CALIFORNIA DEPARTMENT OF FISH AND GAME
WATER AND AQUATIC HABITAT CONSERVATION BRANCH
STREAM EVALUATION PROGRAM

CENTRAL VALLEY ANADROMOUS FISH-HABITAT EVALUATIONS

October 1997 through September 1998

Annual Progress Report
Prepared for
U.S. Fish and Wildlife Service
Central Valley Anadromous Fish Restoration Program

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Funded by the U.S. Fish and Wildlife Service pursuant to the CENTRAL VALLEY PROJECT IMPROVEMENT ACT to improve anadromous fish habitat in California's Central Valley streams

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EXECUTIVE SUMMARY

The Department of Fish and Game is conducting various investigations in Central Valley streams to acquire information on anadromous salmonid populations. Results of the investigations will be used to identify flow requirements for Central Valley anadromous salmonid populations. The work is being conducted pursuant to a cooperative agreement with the US Fish and Wildlife Service to satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B).

The investigations have been ongoing since fall 1995 and have included the Sacramento, Yuba, American, Cosumnes, Calaveras, Stanislaus, Tuolumne and Merced rivers. Data acquired on these streams varies from typing and mapping habitats using aerial photography to comprehensive evaluations and monitoring of spawner populations, spawning distribution, spawning habitat conditions, juvenile rearing, juvenile migration, and juvenile habitat conditions. The comprehensive evaluations have been primarily focused on the reaches of the Sacramento and American rivers that are dependent upon Central Valley Project operations.

To date, results of the investigations on the American River have provided substantial input to the identification of flows in the Anadromous Fishery Restoration Program portion of the CVPIA. The American River data is continually being used by water management and fishery management agencies to identify optimum allocation of flow required for conserving and restoring salmon and steelhead populations in the lower American River. These data along with data collected on the Sacramento River are also being used to globally identify status and needs of salmon and steelhead as they relate to basin-wide management of water and other habitat needs. The National Marine Fisheries Service has and continues to use data collected on winter-run chinook salmon and steelhead in identification of conservation management actions on a real-time basis. Data collected on steelhead is some of the most recent available for the Central Valley and was used by NMFS in their deliberation of listing steelhead as threatened in the Central Valley evolutionary significant unit (ESU). It is presently being used to help identify critical habitat for steelhead in the Central Valley ESU, and in the deliberation of the listing of spring-run, fall-run and late-fall run chinook salmon in the Central Valley ESU.

Data collected to date on the American and Sacramento rivers is also being used to refine methods used to identify habitat needs, including flow, on these rivers as well as on other stream systems within the Central Valley. One of the primary objectives of these investigations is to develop and validate scientifically credible methods for determining habitat requirements for all life stages of salmon and steelhead that depend upon Central Valley streams.

During the reporting period summarized in this report (October 1997 through September 1998) the majority of work was conducted in the Sacramento River. Spawner surveys were conducted on all four races of salmon: juvenile emigration monitoring was conducted on salmon and steelhead; spawning habitat condition investigations were initiated as well as investigation of the response of salmon and steelhead to fluctuating flows. Reconnaissance surveys, primarily aerial photograph based habitat surveys were initiated on the Yuba, Cosumnes and Calaveras rivers.

INTRODUCTION

In July 1995, the California Department of Fish and Game(DFG) entered into an agreement with the U.S. Fish and Wildlife Service (FWS) to evaluate anadromous salmonid habitat requirements in Central Valley streams. Various studies have been developed and are being implemented by the Stream Flow and Habitat Evaluation Program to provide the FWS Central Valley Anadromous Fish Restoration Program with reliable scientific information. The information is to be used by DFG and FWS to develop flow recommendations to satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B).

The basic approach to the evaluations is outlined in "*Proposal to define instream flow and habitat requirements for anadromous resources in Central Valley Streams, September 1994*. The approach includes developing a better understanding of the life history of chinook salmon and steelhead trout emphasizing the relationships between life stage requirements and manageable habitat attributes (e.g., flow, water temperature, channel conditions, etc.). Initially, the evaluations are to be conducted in the Sacramento and American rivers and will include individual investigations of spawning, rearing and migration.

One of the requirements of the agreement is to provide the FWS with annual progress reports (based upon the federal fiscal year, October 1 - September 30). This report covers the investigations conducted in the Sacramento River during the period October 1997 through the last week of September 1998. During that period, DFG conducted seven general investigations (Table 1).

TABLE 1. Investigations conducted by the Department of Fish and Game to determine anadromous salmonid habitat requirements in Central Valley streams - October 1997 through the last week of September 1998.

Investigation	Sacramento River	Yuba, Cosumnes, Calaveras rivers
Habitat mapping	Completed	Initiated
Fall-run chinook salmon spawning	X	NA
Late fall-run chinook salmon spawning	X	NA
Winter-run chinook salmon spawning	X	NA
Spring-run chinook salmon spawning	X	NA
Juvenile salmonid rearing	X	NA
Juvenile salmonid emigration	X	NA

The results of three investigations conducted during the reporting period are presented as Appendices II, III, and IV. These reports cover fall-run, late-fall run and winter-run chinook salmon spawning evaluations in the Sacramento River.

The purpose of this annual progress report is only to generally describe ongoing investigations and to summarize data being collected to evaluate anadromous fish habitat needs in California's Central Valley. No attempt is made herein to analyze data that generally represents less than a complete year's investigation.

UPPER SACRAMENTO RIVER REARING HABITAT EVALUATION

Rearing habitat investigations are intended to determine temporal and spatial distributions of the various juvenile life stages of anadromous salmonids in the upper Sacramento River. These investigations compliment juvenile emigration evaluations and should be conducted year around to fully understand behavior of juvenile salmonids relative to habitat conditions. Some of the information to be gained from our studies include: relative importance of upper river habitat to different life stages under varying conditions; temporal and physical significance of various habitat conditions; and significance of stream conditions downstream of the study area - basically an overall understanding of the relationship between fish and habitat in the upper river as it is influenced by potentially manageable biotic and abiotic, habitat attributes. The results presented here represent the third year of a 5-year study. Sampling with seines and rotary screw traps (RST) was suspended after 16 September 1997 to comply with National Marine Fisheries Service's (NMFS) Section 10 permit conditions. The Department had exceeded the winter-run take limit for 1997-98, therefore halted sampling until March 1998 when NMFS permitted sampling to restart.

Evaluation of anadromous salmonid rearing habitat in the upper Sacramento River using seine and snorkel surveys was initiated in August 1996. The study area is located between river mile 271 (just below the mouth of Battle Creek) and river mile 302 (Keswick Dam) (Figure 1). Most sample sites are located above Battle Creek, hence upstream of the influence of Coleman National Fish Hatchery. Sample sites were selected from 143 habitat units located in the study area; these units had been previously mapped by the Department (DFG 1997, Appendix I). Habitat mapping was based on channel morphology using a stratified classification system similar to that used on the American River (Snider et al. 199?). Habitat types (e.g., pool, riffle, run, and glide) were stratified by habitat zone (flatwater, bar complex, side channel, and off channel). Our goal was to sample 3 replicates of 11 randomly selected habitats twice per month. For this report, all the data from habitats distinguished by zone (i.e. flatwater pool and bar complex pool) were combined to represent 4, instead of 11 habitats: riffle, pool, glide, and run (no off-channel sites are present in study area).

Snorkel surveys consisted of two swimmers simultaneously surveying a 150-ft long section randomly selected along each bank of the habitat unit. Data collected included: species, size in 25-mm size classes, and general habitat attributes (mean depth, mean velocity, cover, etc.). During the seining surveys, habitat units were sampled with a 50 x 4-ft beach seine. Up to two seine hauls were made per unit. Data acquired included number of salmonids (by species), size of up to 50 salmon and trout, per haul, (i.e., fork length [FL] to the nearest 0.5 mm, and weight, to the nearest 0.1 g), and general habitat attributes of the site seined.

A total of 205 sites was sampled from 31 May (week 23) through 30 September 1998 (week 39). Survey sites included 63 riffles, 29 pools, 56 glides, and 57 runs (no off-channel sites)(Table 2); 143 units mapped, 86 were snorkeled and 20 were seined (Table 3).

TABLE 2. Weekly distribution of habitat types sampled during the upper Sacramento River rearing habitat evaluation study, October 1997- September 1998.

Week	Riffle	Pool	Glide	Run	Off-channel
		No sampling weeks 40-22			
23	1	2	3	1	0
24	5	1	0	4	0
25	5	0	4	2	0
26	2	0	2	6	0
27	2	2	0	0	0
28	2	2	3	2	0
29	6	4	5	3	0
30	5	3	6	5	0
31	4	0	2	0	0
32	3	0	3	2	0
33	2	3	6	8	0
34	3	2	3	5	0
35	5	4	4	3	0
36	12	2	4	6	0
37	2	0	4	4	0
38	4	3	5	5	0
39	0	1	2	1	0
Total	**63**	**29**	**56**	**57**	**0**

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TABLE 3. Distribution of habitat units (identification numbers per Appendix Table I) sampled by both seine and snorkel during the upper Sacramento River rearing habitat evaluation study, October 1997 - September 1998.

Week	Seine only	Seine and Snorkel	Snorkel only
		No sampling from weeks 40 - 22	
23	-	-	38, 39, 80, 82, 103, 110, 130
24	-	-	15, 16, 20, 23, 32, 36, 52, 64, 85, 86
25	23	18, 21, 30, 31, 38	-
26	-	63, 75, 82, 91	7, 8
27	-	123, 130	-
28	-	104, 110	118, 123, 130, 133, 135
29	-	6, 10	1, 11, 18, 39, 44, 47, 67, 88, 100, 101, 106, 119
30	-	-	36, 42, 45, 48, 50, 51, 67, 75, 91, 101, 106, 112, 131, 133, 136, 137, 139, 141
31	-	6, 10, 18	-
32	18, 30	21, 38, 63	-
33	-	81, 82, 91, 104, 110, 130	2, 3, 5, 7, 34, 45, 123
34	-	-	41, 52, 57, 85, 88, 89. 105, 106, 109, 112, 118, 142
35	-	-	12, 15, 25, 27, 30, 36, 42, 47, 52, 56, 69, 70, 77, 81, 83, 94
36	-	6, 10, 18, 21, 30, 31, 38, 63, 69, 75, 77, 82	-
37	-	81, 91, 98, 104, 110	-
38	-	-	8, 15, 24, 25, 31, 38, 40, 43, 48, 62, 102, 108, 117, 125, 131, 139, 142
39	-	-	121, 129, 140, 142

Snorkel Survey Results

Chinook Salmon

A total of 22,337 juvenile chinook salmon was counted during the snorkel survey (Table 4). The mean weekly number of salmon counted per sample site ranged from 14.6 (week 25) to 963.5 (week 27).

The majority of salmon counted were in the 51-75 mm FL range (52.3%) (Table 4; Figure 2). For the remaining size categories, 1.4% were <25 mm FL, 41.2% were in the 26-50 mm FL range, 4.8% in the 76-100 mm FL range, and 0.3% were >100 mm FL. Salmon in the 26-50 and 51-75 mm size ranges dominated the counts during most weeks (Figures 3-7).

Temporal salmon distribution over time varied both among and within habitat types (Table 5; Figures 8-12). The mean weekly salmon count was greatest for runs (0.309 fish/ft). Riffle counts averaged 0.297 fish/ft. Glide counts averaged 0.205 fish/ft followed closely by pools which averaged 0.200 fish/ft. When fish were the most abundant (week 30), the number of fish/ft was greatest in runs, followed by glides, riffles, and lastly pools.

Rainbow trout (steelhead)

A total of 11,768 rainbow trout was counted during the snorkel survey (Table 6). The mean weekly number of rainbow trout counted per sample site ranged from 0.1 (week 23) to 196.3 (week 34).

Most trout observed were in the 51-75 mm FL range (40.0%) (Table 6; Figure 13). For the remaining size categories, 8.4% were <25 mm FL, 36.9% were in the 26-50 mm FL range, 10.2% were in the 76-100 mm FL range, and 4.5% were >100 mm FL. The greatest numbers of the larger fish (≥76 mm FL) were observed during weeks 33, 34, 36, and 38 (June and August) (Figures 14-18); they were absent during weeks 23, 28, 29, and 31 (May and July). The greatest numbers of smaller fish (≤50 mm FL) were observed during weeks 29, 30, 33, and 34; they were present every week sampled.

Rainbow trout distribution over time varied among and within habitat types (Table 7; Figures 19-23). The overall mean numbers of fish/ft were 0.221 for runs, 0.117 for glides, 0.098 for riffles, and 0.072 for pools. Runs were the favored habitat of both large and small rainbow trout.

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TABLE 4. Summary of chinook salmon data collected during snorkel surveys of rearing habitat in the upper Sacramento River, October 1997 - September 1998.

Week (beginning date)	Number of sites	Total Count	#/site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
No sites sampled weeks 40-22								
23 (31 May)	7	258	36.9	0	20.9	78.7	0	0.4
24 (07 Jun)	10	1,047	104.7	0	13.5	68.3	18.2	0
25 (14 Jun)	5	73	14.6	0	9.6	84.9	5.5	0
26 (21 Jun)	6	802	133.7	7.5	30.2	62.3	0	0
27 (28 Jun)	2	1,927	963.5	2.6	33.7	59.7	3.9	0.1
28 (05 Jul)	7	3,199	457.0	0	35.2	64.8	0	0
29 (12 Jul)	16	3,995	249.7	1.6	53.0	44.1	1.3	0.1
30 (19 Jul)	19	4,033	212.3	0	36.6	57.0	6.0	0.4
31 (26 Jul)	3	145	48.3	0	65.5	34.5	0	0
32 (02 Aug)	3	656	218.7	22.9	53.5	21.3	2.3	0
33 (09 Aug)	13	983	75.6	0.2	47.1	31.5	21.1	0.1
34 (16 Aug)	13	1,734	133.4	0	32.3	57.9	8.7	1.2
35 (23 Aug)	16	675	42.2	0	45.5	51.4	0.7	2.4
36 (30 Aug)	12	767	63.9	0	33.4	53.3	12.9	0.4
37 (06 Sep)	5	510	102	0	70.4	24.1	4.90	0.6
38 (13 Sep)	17	1,142	67.2	0	55.4	44.0	0	0.5
39 (20 Sep)	4	391	97.8	0	92.8	6.9	0	0.3
Total (mean)	158	22,337	(141.4)	(1.4)	(41.2)	(52.3)	(4.8)	(0.3)

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TABLE 5. Summary of total counts and counts per foot, by habitat type, of chinook salmon counted during snorkel survey of upper Sacramento River rearing habitat, October 1997 - September 1998.

Week	Riffle			Pool			Glide			Run		
	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft
	No sites sampled weeks 40-22											
23	1	1	0.003	2	52	0.058	3	204	0.124	1	1	0.002
24	5	495	0.183	1	0	0	0	0	0	4	552	0.230
25	2	10	0.008	0	0	0	2	55	0.041	1	8	0.013
26	1	1	0.003	0	0	0	2	25	0.024	3	776	0.431
27	1	1,877	2.503	1	50	0.083	0	0	0	0	0	0
28	2	1,316	1.097	2	803	0.892	2	1,050	0.875	1	30	0.050
29	4	477	0.318	4	1,299	0.619	5	755	0.252	3	1,464	0.887
30	5	599	0.266	3	185	0.154	6	1,451	0.440	5	1,798	0.599
31	2	125	0.139	0	0	0	1	20	0.033	0	0	0
32	1	26	0.087	0	0	0	1	400	0.667	1	230	0.383
33	2	376	0.313	2	1	0.002	4	447	0.186	5	159	0.050
34	3	165	0.122	2	30	0.029	3	360	0.240	5	1,179	0.414
35	5	54	0.023	4	117	0.060	4	130	0.054	3	374	0.208
36	6	494	0.157	1	1	0.001	2	6	0.006	3	266	0.148
37	1	50	0.167	0	0	0	2	55	0.046	2	405	0.300
38	4	429	0.204	3	40	0.021	5	178	0.054	5	495	0.165
39	0	0	0	1	0	0	2	153	0.128	1	238	0.397
Total (mean)	45	6,495	(0.297)	26	2,578	(0.200)	44	5,289	(0.205)	43	7,975	(0.309)

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TABLE 6. Summary of rainbow trout data collected during snorkel surveys of rearing habitat in the upper Sacramento River, October 1997 - September 1998.

Week (beginning date)	Number of sites	Total Count	#/site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
No sites sampled weeks 40-22								
23 (31 May)	7	1	0.1	0	100.0	0	0	0
24 (07 Jun)	10	197	19.7	12.7	34.0	29.9	19.3	4.1
25 (14 Jun)	5	23	4.6	0	87.0	8.7	4.3	0
26 (21 Jun)	6	369	61.5	2.7	27.1	69.4	0.8	0.5
27 (28 Jun)	2	316	105.3	31.6	47.5	17.4	3.2	0.3
28 (05 Jul)	7	260	37.1	0	49.6	50.4	0	0
29 (12 Jul)	16	825	51.6	38.8	33.6	27.6	0	0
30 (19 Jul)	19	1,617	85.1	0	54.5	40.7	3.3	1.5
31 (26 Jul)	3	58	19.3	0	13.8	86.2	0	0
32 (02 Aug)	3	522	174.0	14.4	40.2	32.6	4.8	8.0
33 (09 Aug)	13	1,746	134.3	18.6	41.6	12.4	10.1	17.2
34 (16 Aug)	13	2,552	196.3	2.2	35.3	38.6	22.8	1.2
35 (23 Aug)	16	594	37.1	3.7	39.1	43.6	9.8	3.9
36 (30 Aug)	12	737	61.4	1.4	34.1	38.0	22.7	3.9
37 (06 Sep)	5	198	39.6	20.2	35.9	35.4	7.6	1.0
38 (13 Sep)	17	1,744	102.6	0.1	18.0	73.8	4.2	4.0
39 (20 Sep)	4	9	2.3	0	88.9	0	0	11.1
Total (mean)	158	11,768	74.5	(8.4)	(36.9)	(40.0)	(10.2)	(4.5)

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TABLE 7. Summary of total counts and counts per foot, by habitat type, of rainbow trout counted during snorkel surveys of upper Sacramento River rearing habitat, October 1997 - September 1998.

Week	Riffle			Pool			Glide			Run		
	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft
No sites sampled weeks 40-22												
23	1	0	0	2	1	0.001	3	0	0	1	0	0
24	5	148	0.055	1	0	0	0	0	0	4	49	0.020
25	2	1	0.001	0	0	0	2	13	0.010	1	9	0.015
26	1	0	0	0	0	0	2	10	0.010	3	359	0.199
27	1	236	0.315	1	80	0.133	0	0	0	0	0	0
28	2	11	0.009	2	65	0.072	2	104	0.087	1	80	0.133
29	4	17	0.011	4	220	0.105	5	322	0.107	3	266	0.161
30	5	253	0.112	3	212	0.177	6	532	0.161	5	620	0.207
31	2	50	0.056	0	0	0	1	8	0.013	0	0	0
32	1	0	0	0	0	0	1	437	0.728	1	85	0.142
33	2	414	0.345	2	0	0	4	234	0.098	5	1,098	0.349
34	3	211	0.156	2	26	0.025	3	438	0.292	5	1,877	0.659
35	5	40	0.017	4	117	0.060	4	423	0.176	3	14	0.008
36	6	213	0.068	1	11	0.015	2	124	0.118	3	389	0.216
37	1	14	0.047	0	0	0	2	83	0.069	2	101	0.075
38	4	528	0.251	3	191	0.098	5	278	0.084	5	747	0.249
39	0	0	0	1	0	0	2	9	0.008	1	0	0
Total (mean)	45	2,136	(0.098)	26	923	(0.072)	44	3,015	(0.117)	43	5,694	(0.221)

Seine Survey Results

Chinook salmon

A total of 576 salmon were collected from 47 sites by seine (Table 8). The weekly mean size of salmon ranged from 35.7 mm FL (week 32) to 60.0 mm FL (week 25). Recently emergent-sized fish ($\leq$35 mm FL) were observed during the weeks of 26, 28, 32, 33, 36, and 37. Smolt-sized fish ($\geq$70 mm FL) were observed during weeks 25, 26, 28, 36, and 37.

Habitat types were not equally represented in the overall sampling effort. Catch per habitat unit were as follows: 18 riffles yielded a mean catch 7.9 fish/site, 3 pools yielded of 1.7 fish/site, 12 glides yielded 2.2 fish/site, and 14 runs yielded 28.7 fish/site (Table 8).

The size distribution of seine-caught fish are presented in Figures 24-26. The size ranges observed during the snorkel surveys were much greater than those observed during the seining surveys for the weeks that both sampling techniques were used (weeks 25, 26, 28, 29, 31, 32, 33, 36, and 37).

Rainbow trout (steelhead)

A total of 37 rainbow trout was collected from 47 sites (Table 9). The mean weekly mean size ranged from 29.0 mm FL (week 33) to 54.3 mm FL (week 26). Recently emerged fish (<35 mm FL) were collected during weeks 25, 29, 32, 33, and 36. Larger smolt-sized fish ($\geq$100 mm FL) were not caught this year.

Catches per habitat unit were as follows: 18 riffles yielded a mean catch of 1.2 fish per site, 3 pools yielded 1.0 fish per site, 12 glides yielded 0.2 fish per site, and 14 runs yielded 0.7 fish per site (Table 9).

The size distributions of seine caught fish are presented in Figures 27-29. The size ranges of seine-caught trout was different from the size ranges of trout observed during the snorkel surveys. For 5 the 10 weeks that both seines and snorkel surveys were conducted (27, 29, 33, 36, and 37), more larger trout (>100 mm FL) were observed during the snorkel surveys than were captured in seines. The discrepancy may be due to larger trout being better able to avoid the seine.

TABLE 8. Weekly catch statistics by habitat type for chinook salmon caught by beach seine in the upper Sacramento River, October 1997- September 1998.

Week (beginning date)	Riffle			Pool			Glide			Run			Total		
	No. sites	Count	FL mean (range)	No. sites	Count	FL mean (range)	No. sites	Count	FL mean (range)	No. sites	Count	FL mean (range)	No. sites	Count	FL mean (range)
25 (14 Jun)	3	0	-	No sites sampled			2	1	45.0	1	2	67.5 (64-71)	6	3	60.0 (45-71)
26 (21 Jun)	1	0	-	No sites sampled			No sites sampled			3	341	40.5 (31-78)	4	341	40.5 (31-78)
27 (28 Jun)	1	0	-	1	0	-	No sites sampled			No sites sampled			2	0	-
28 (05 Jul)	No sites sampled			No sites sampled			1	9	62.3 (42-83)	1	19	42.4 (35-55)	2	28	48.8 (35-83)
29 (12 Jul)	2	1	47.0	No sites sampled			No sites sampled			No sites sampled			2	1	47.0
30 (19 Jul)	No sites sampled			No sites sampled			No sites sampled			No sites sampled 00-			No sites sampled		
31 (26 Jul)	2	1	46.0	No sites sampled			1	1	41.0	No sites sampled			3	2	43.5 (41-46)
32 (02 Aug)	2	0	-	No sites sampled			2	14	35.1 (32-42)	1	6	37.0 (35-41)	5	20	35.7 (32-42)
33 (09 Aug)	No sites sampled			1	2	46.5 (44-49)	2	0	-	3	7	43.7 (35-57)	6	9	44.3 (35-57)
34 (16 Aug)	No sites sampled			No sites sampled			No sites sampled			No sites sampled			No sites sampled		
35 (23 Aug)	No sites sampled			No sites sampled			No sites sampled			No sites sampled			No sites sampled		
36 (30 Aug)	6	16	51.4 (34-84)	1	3	40.7 (36-49)	2	1	37.0	3	5	45.4 (37-57)	12	25	48.4 (34-84)
37 (06 Sep)	1	125	43.6 (30-70)	No sites sampled			2	0	-	2	22	36.2 (33-40)	5	147	42.5 (30-70)
Totals (mean)	18	143	44.5 (30-84)	3	5	43.0 (36-49)	12	26	45.2 (32-83)	14	402	40.6 (31-78)	47	576	42.1 (30-84)

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TABLE 9. Weekly catch statistics by habitat type for rainbow trout by beach seine in the upper Sacramento River, October 1997 - September 1998.

Week (beginning date)	Riffle			Pool			Glide			Run			Total		
	No. sites	Count	FL mean (range)	No. sites	Count	FL mean (range)	No. sites	Count	FL mean (range)	No. sites	Count	FL mean (range)	No. sites	Count	FL mean (range)
25 (14 Jun)	3	1	85.0	No sites sampled			2	1	24.0	1	1	29.0	6	3	46.0 (24-85)
26 (21 Jun)	1	0	-	No sites sampled			No sites sampled			3	4	54.3 (38-92)	4	4	54.3 (38-92)
27 (28 Jun)	1	0	-	1	0	-	No sites sampled			No sites sampled			2	0	-
28 (05 Jul)	No sites sampled			No sites sampled			1	0	-	1	0	-	2	0	-
29 (12 Jul)	2	13	36.8 (23-48)	No sites sampled			No sites sampled			No sites sampled			2	13	36.8 (23-48)
30 (19 Jul)	No sites sampled			No sites sampled			No sites sampled			No sites sampled			No sites sampled		
31 (26 Jul)	2	0	-	No sites sampled			1	0	-	No sites sampled			3	0	-
32 (02 Aug)	2	5	30.4 (24-35)	No sites sampled			2	1	36.0	1	1	39.0	5	7	32.4 (24-39)
33 (09 Aug)	No sites sampled			1	0	-	2	0	-	3	2	29.0 (25-33)	6	2	29.0 (25-33)
34 (16 Aug)	No sites sampled			No sites sampled			No sites sampled			No sites sampled			No sites sampled		
35 (23 Aug)	No sites sampled			No sites sampled			No sites sampled			No sites sampled			No sites sampled		
36 (30 Aug)	6	2	46.0 (39-53)	1	3	34.3 (33-36)	2	0	-	3	1	37.0	12	6	38.7 (33-53)
37 (06 Sep)	1	1	41.0	No sites sampled			2	0	-	2	1	38.0	5	2	39.5 (38-41)
Totals (mean)	18	22	38.5 (23-85)	3	3	34.3 (33-36)	12	2	30.0 (24-36)	14	10	41.8 (25-92)	47	37	38.6 (23-92)

UPPER SACRAMENTO RIVER EMIGRATION SURVEY

Emigrating juvenile salmonids were monitored at sites near the Balls Ferry Bridge (RM 278) and the Deschutes Road Bridge (RM 281). The purpose of the monitoring is to determine the timing and relative abundance of salmon and rainbow trout (potentially steelhead) emigration relative to precedent conditions of spawning and rearing in the upper natal stream. The results provided in this report are for the period from 10 March (week 11) through 30 September 1998 (week 40). Sampling is normally conducted with two rotary screws traps at RM 278 and one at RM 281.

Sampling had to be delayed until 10 March 1998 (week 11) because we had exceeded the Section 10 take limit for winter-run salmon for the 1 July 1997 through 30 June 1998 period and needed to get special authorization from NMFS to restart sampling prior to 1 July 1998. From 9 June (week 24) to 26 July (week 31) one of the Balls Ferry traps was not operated because it was broken. After repairing this trap, it was operated 4 days during week 31 (26 July) and then it was raised. Beginning on 10 August (week 33), the winter-run catch began to drastically increase so we curtailed our sampling efforts to avoid exceeding our take limit for 1998-99 season.

Data recorded when the screw traps were checked included number of hours fished and juvenile salmonids collected by species. Race for chinook salmon was determined using the length-at-time criteria developed by Frank Fisher (Department of Fish and Game - Red Bluff). All salmon identified as winter run, spring run, and late-fall run were measured and weighted (FL in mm and weight in g). Up to 300 fall-run-sized salmon were randomly selected per trap up to twice daily, then measured and weighted. All juvenile rainbow trout were counted and measured.

Trap efficiency was evaluated by marking a portion of salmon captured (winter run were never marked). Fish were marked with dyes either by injecting them with Alcian blue or, rarely, by bathing them in Bismark brown. Fish captured and marked at Balls Ferry were transported upstream about 2,500 feet then released. Those marked at Deschutes Road Bridge were released at that site. All salmon captured in the Balls Ferry traps were checked for marks as they were measured. The Deschutes Road trap was normally operated only 2 days/week to capture, mark, and then release fish for later recapture at the downstream traps.

Emigration Results

Chinook Salmon

Juvenile salmon were collected every week sampled (Table 10; Figure 30). Mean weekly size ranged from 37.6 mm FL (week 36) to 64.7 mm FL (week 24) (Figure 31). Both recently emerged-sized fish (≤ 35 mm FL) and larger smolt-sized fish (≥ 70 mm FL) were captured every week that samples were collected (Appendix II; Figures 1-12).

Catch rates ranged from 0.69 fish/h (week 22) to 42.68 fish/h (week 40) (Table 10; Figure 30). Due to Section 10 permit restrictions, we did not fish the screw traps during February the month that we could expect to get the greatest number of fall-run juveniles. The greatest catches were observed during weeks 12, 15, 16, and 17 (Table 10; Figure 31). A total of 49,257 chinook salmon was counted. Of this total, there were 571 spring-run sized salmon; 29,292 fall-run sized salmon; 10,620 late-fall-run sized salmon; and 8,774 winter-run sized salmon. When sampling starting in week 12 (10 March), the number of fall run emigrating had likely already peaked (Figure 32). Late-fall salmon catch peaked during weeks 16-20 (12 April through 9 May 1998). Spring run peaked in weeks 15-16 (5-18 April 1998). Winter-run first appeared in week 28 (5 July) and we greatly reduced our sampling efforts starting in week 33 (10 August 1998) to avoid exceeding the Section 10 take limit.

Spring-run sized salmon ranged from 65 to 119 mm FL (Figure 33). Fall run ranged from 27 to 140 mm FL; late-fall run ranged from 27 to 105 mm FL; and winter run ranged from 28 to 205 mm FL.

Trapping efficiency, as measured by the recovery of dye-marked fish, showed that efficiency was highest during March and April (Table 11). This may be biased by the lack of enough fish to mark to monitor trap efficiency throughout the year.

Rainbow Trout (Steelhead)

Rainbow trout (potentially steelhead) were collected throughout the survey (Table 12; Figure 34). Mean week size ranged from 29.0 mm FL (week 14) to 103.8 mm FL (week 11). Total catch ranged from 1 (week 40) to 202 (week 32). Catch rate ranged from 0.03 fish/h (week 11) to 0.69 fish/h (week 20) (Figure 35). Rainbow trout ranged from 21 to 200 mm FL.

TABLE 10. Summary of chinook salmon catch statistics, upper Sacramento River emigration survey using rotary screw traps including the Deschutes Road trap, October 1997 - September 1998.

Week	Start Date	Weekly Catch	Catch/h	Size Statistics			
				Mean	Minimum	Maximum	SD
No sampling weeks 40 - 10							
11	08 Mar	2,719	13.82	38.0	29	145	7.22
12	15 Mar	9,356	28.61	37.7	27	138	7.22
13	22 Mar	No sampling week 13					
14	29 Mar	1,010	4.07	37.7	31	87	7.12
15	05 Apr	4,024	11.55	41.1	28	143	12.29
16	12 Apr	7,793	23.90	45.5	27	205	17.29
17	19 Apr	4,971	15.10	41.8	29	195	13.79
18	26 Apr	2,163	5.09	45.7	31	121	17.35
19	03 May	1,438	3.38	51.2	30	111	19.60
20	10 May	1,210	3.11	52.2	27	112	18.65
21	17 May	531	1.78	54.3	28	110	17.24
22	24 May	95	0.69	55.6	31	92	18.11
23	31 May	462	1.56	62.9	29	98	15.07
24	07 Jun	490	2.07	64.7	30	119	14.50
25	14 Jun	663	2.98	57.4	30	99	18.67
26	21 Jun	603	1.95	55.2	30	111	20.73
27	28 Jun	328	1.56	58.0	33	99	20.83
28	05 Jul	370	2.47	55.7	28	98	21.09
29	12 Jul	1,096	6.67	50.1	31	101	18.81
30	19 Jul	826	5.04	47.0	31	99	17.96
31	26 Jul	947	5.07	46.7	30	110	18.64
32	02 Aug	1,399	7.69	44.3	31	104	17.34
33	09 Aug	876	11.68	46.0	29	111	17.39
34	16 Aug	538	10.35	40.3	34	93	10.35

TABLE 10 (cont.). Summary of chinook salmon catch statistics, upper Sacramento River emigration survey using rotary screw traps including the Deschutes Road trap, October 1997 - September 1998.

Week	Start Date	Weekly Catch	Catch/h	Size Statistics			
				Mean	Minimum	Maximum	SD
35	23 Aug	772	29.96	41.6	33	115	14.21
36	30 Aug	708	14.83	37.6	28	95	10.47
37	06 Sep	888	19.73	40.0	30	103	13.84
38	13 Sep	710	31.91	43.3	32	109	19.10
39	20 Sep	1,332	28.65	37.8	31	120	9.49
40	27 Sep	939	42.68	37.9	32	140	12.20
Total		49,257	8.26	45.5	27	205	16.81

TABLE 11. Results of Balls Ferry trap rotary screw trap efficiency evaluations conducted with marked chinook salmon during the upper Sacramento River emigration survey, October 1997 - September 1998.

Week	Number marked	Number recaptured	Efficiency (%)
		No sampling weeks 40-10	
11	1,701	27	1.59
12	5,455	95	1.74
13		No sampling week 13	
14	792	28	3.54
15	2,011	48	2.39
16	3,876	51	1.32
17	1,529	21	1.37
18	861	7	0.81
19	508	8	1.57
20	493	6	1.22
21	259	2	0.77
22	8	0	-
23	206	0	-
24	338	0	-
25	282	0	-
26	183	1	0.55
27	222	1	0.45
28	166	1	0.60
29	784	4	0.51
30	384	1	0.26
31	271	1	0.37
32	247	1	0.40
33	191	0	-
34	0	0	-
35	52	0	-
36	83	0	-

TABLE 11 (cont.). Results of Balls Ferry trap rotary screw trap efficiency evaluations conducted with marked chinook salmon during the upper Sacramento River emigration survey, October 1997 - September 1998.

Week	Number marked	Number recaptured	Efficiency (%)
37	0	0	-
38	0	0	-
39	0	0	-
40	0	0	-
Total	20,902	303	1.45

TABLE 12. Summary of rainbow trout catch statistics, upper Sacramento River emigration survey using rotary screw traps including the Deschutes Road trap, October 1997 - September, 1998.

Week	Start Date	Weekly Catch	Catch/h	Size Statistics			
				Mean	Minimum	Maximum	SD
			No sampling weeks 40 - 10				
11	08 Mar	6	0.03	103.8	56	180	40.63
12	15 Mar	14	0.04	85.3	25	160	40.34
13	22 Mar			No sampling Week 13			
14	29 Mar	2	0.01	29.0	26	32	3.00
15	05 Apr	10	0.03	65.0	26	140	38.42
16	12 Apr	36	0.11	61.6	26	86	13.46
17	19 Apr	91	0.28	63.0	31	111	12.09
18	26 Apr	113	0.27	57.5	27	90	12.89
19	03 May	201	0.47	57.5	29	195	16.18
20	10 May	246	0.63	53.6	32	200	13.70
21	17 May	76	0.26	57.8	25	90	12.12
22	24 May	23	0.17	52.8	37	71	7.92
23	31 May	65	0.22	62.9	45	98	11.57
24	07 Jun	110	0.46	57.7	27	98	11.75
25	14 Jun	79	0.35	57.4	24	82	13.11
26	21 Jun	34	0.11	52.6	23	115	21.74
27	28 Jun	25	0.12	49.3	27	94	20.44
28	05 Jul	19	0.13	49.3	21	90	19.94
29	12 Jul	74	0.45	38.1	22	93	18.10
30	19 Jul	85	0.52	39.2	21	99	20.21
31	26 Jul	109	0.58	39.3	21	111	20.52
32	02 Aug	37	0.20	44.7	22	99	20.44
33	09 Aug	27	0.36	52.8	25	99	18.62
34	16 Aug	14	0.27	45.4	31	84	13.20

TABLE 12 (cont.). Summary of rainbow trout catch statistics, upper Sacramento River emigration survey using rotary screw traps including the Deschutes Road trap, October 1997 - September, 1998.

Week	Start Date	Weekly Catch	Catch/h	Size Statistics			
				Mean	Minimum	Maximum	SD
35	23 Aug	28	0.36	52.4	33	79	11.59
36	30 Aug	20	0.42	51.0	33	175	31.42
37	06 Sep	14	0.31	52.2	35	76	12.43
38	13 Sep	2	0.09	54.5	48	61	6.50
39	20 Sep	4	0.09	66.3	42	125	34.16
40	27 Sep	1	0.05	45.0	45	45	-
Total		1,565	0.26	53.7	21	200	18.77

UPPER SACRAMENTO RIVER
SALMON SPAWNING EVALUATION

Spawner surveys were conducted continuously throughout the reporting period. Survey effort and reach changed seasonally to accommodate the attributes of the particular salmon run being investigated. A detailed discussion of the methods and results associated with the fall-run, late-fall run and winter-run surveys are presented in appendices III, IV and V. These reports account for the period extending from late-September 1997 through late-August 1998.

Spawning occurred during every month (Figure). Spawning activity was relatively light during the traditional spring-run chinook salmon spawning period (early September through early October). A clear break in spawning distribution before and after this period indicates that spring run spawn in the survey reach but that abundance is low.

RECONNAISSANCE HABITAT SURVEYS

In preparation for future investigations, aerial photographs were taken of the Yuba, Cosumnes and Calaveras rivers. The Cosumnes and Calaveras river surveys were made during fall 1997 to include spawning activity. The Yuba River was surveyed in late-September 1998 to determine the presence and distribution of spring-run chinook salmon spawning activity. These photographs are being evaluated to determine habitat type distribution and abundance at the flows present during the photograph survey, and to identify spawning distribution.

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CDFG. 1997. Central Valley anadromous fish-habitat evaluations, October 1995 - September 1997. CA. Dept. of Fish and Game, Stream Evaluation Program, Env. Serv. Div.

Snider, W.M., D.B. Christophel, B.L. Jackson, and P.M. Bratovich. 1992. Habitat characterization of the Lower American River. Beak Consultants, Inc.

FIGURES

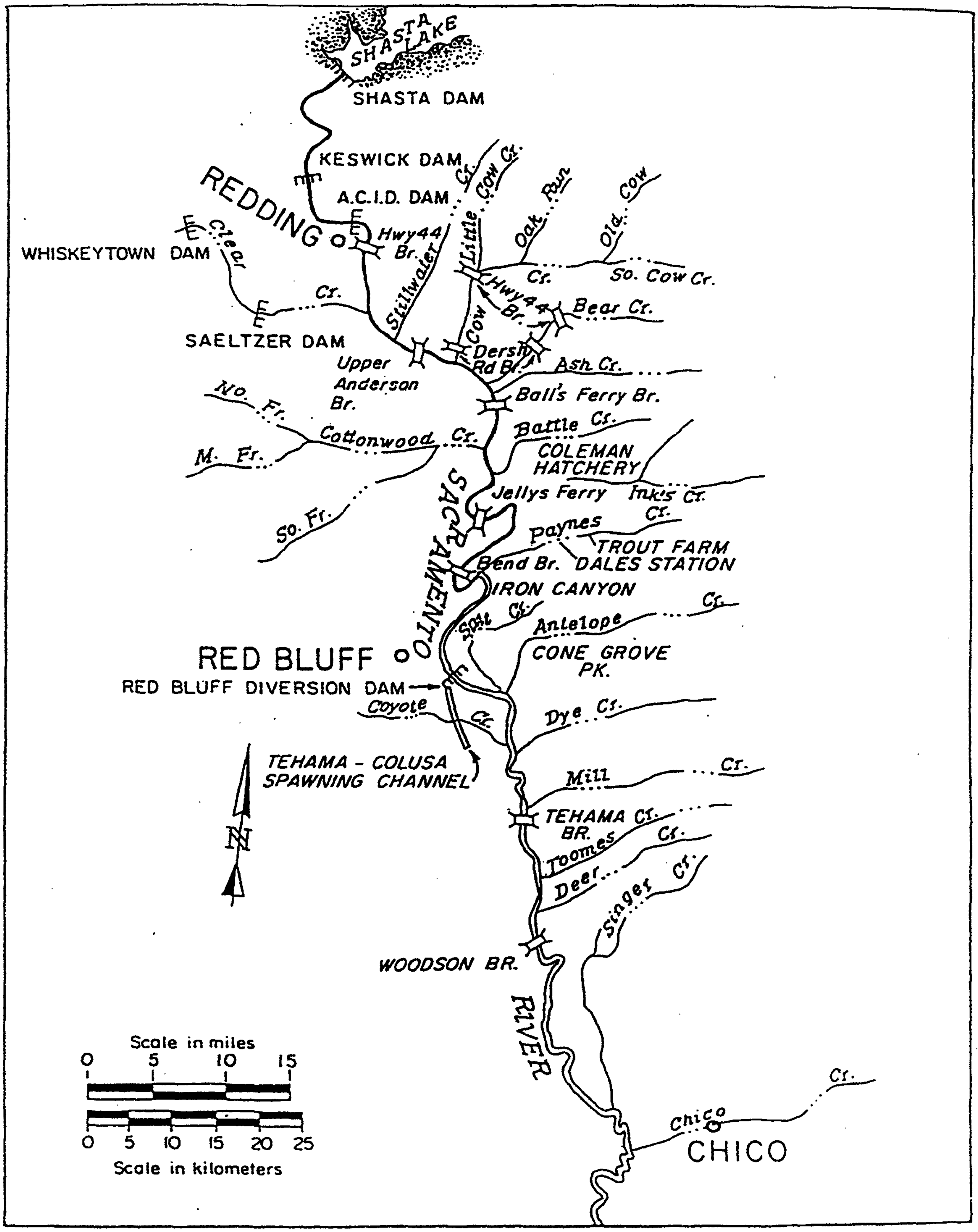

Figure 1. Upper Sacramento River.

D-025515

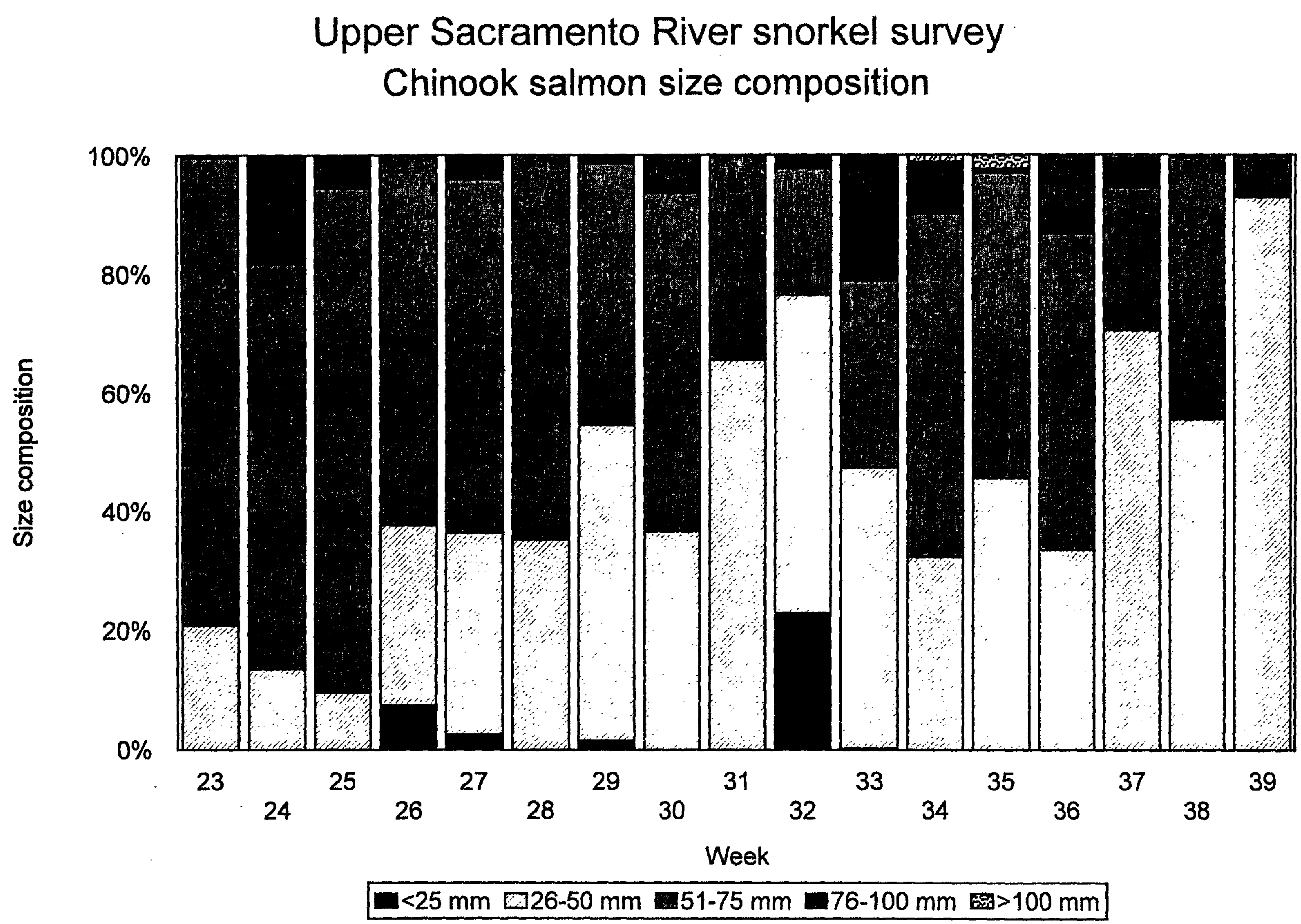

Figure 2. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, October 1997 - September 1998. No sites were sampled Week 40 through Week 22.

Upper Sacramento River snorkel survey, 1997-1998
Chinook salmon size composition

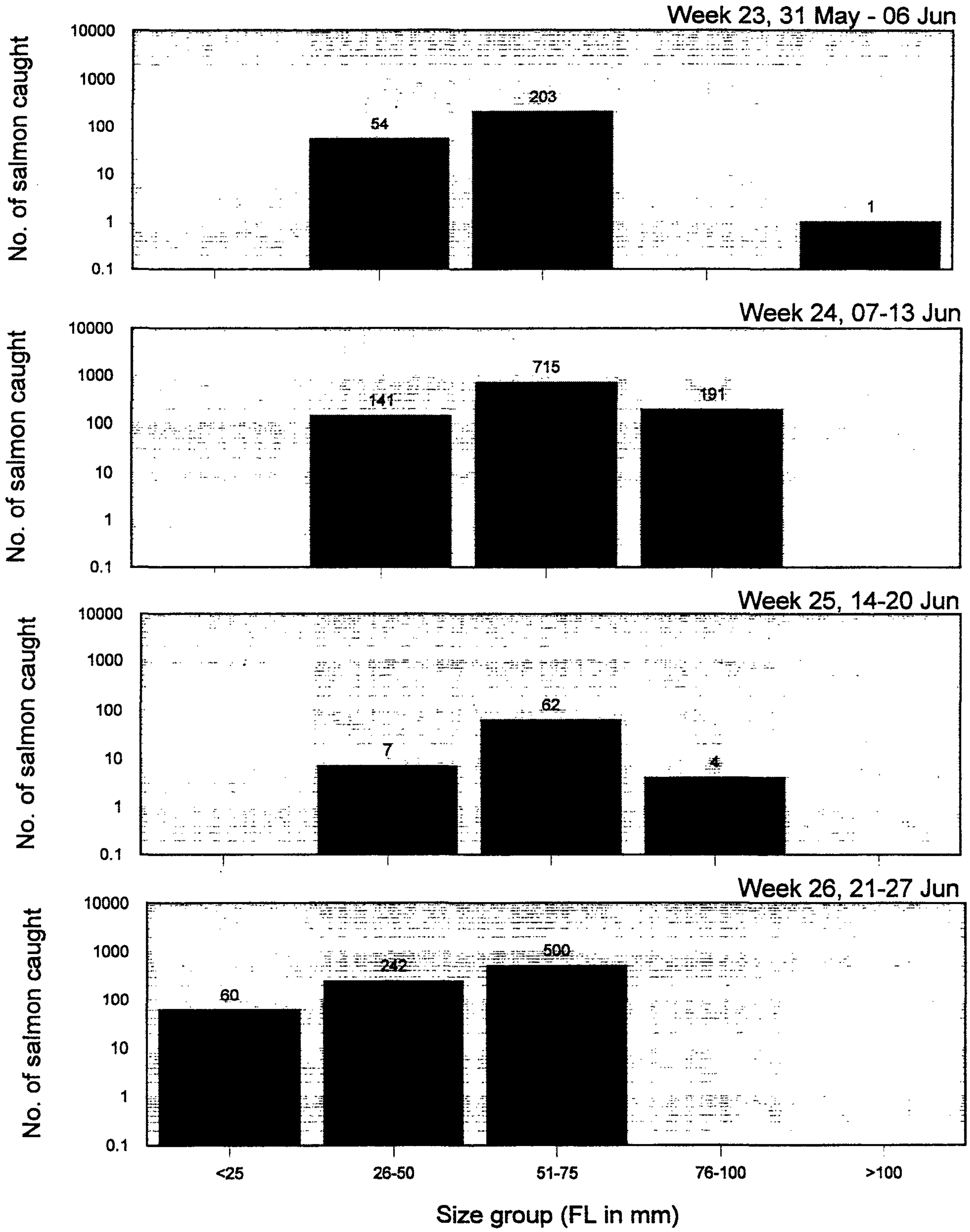

Figure 3. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 31 May - 27 June, 1998.

Upper Sacramento River snorkel survey, 1997-1998
Chinook salmon size composition

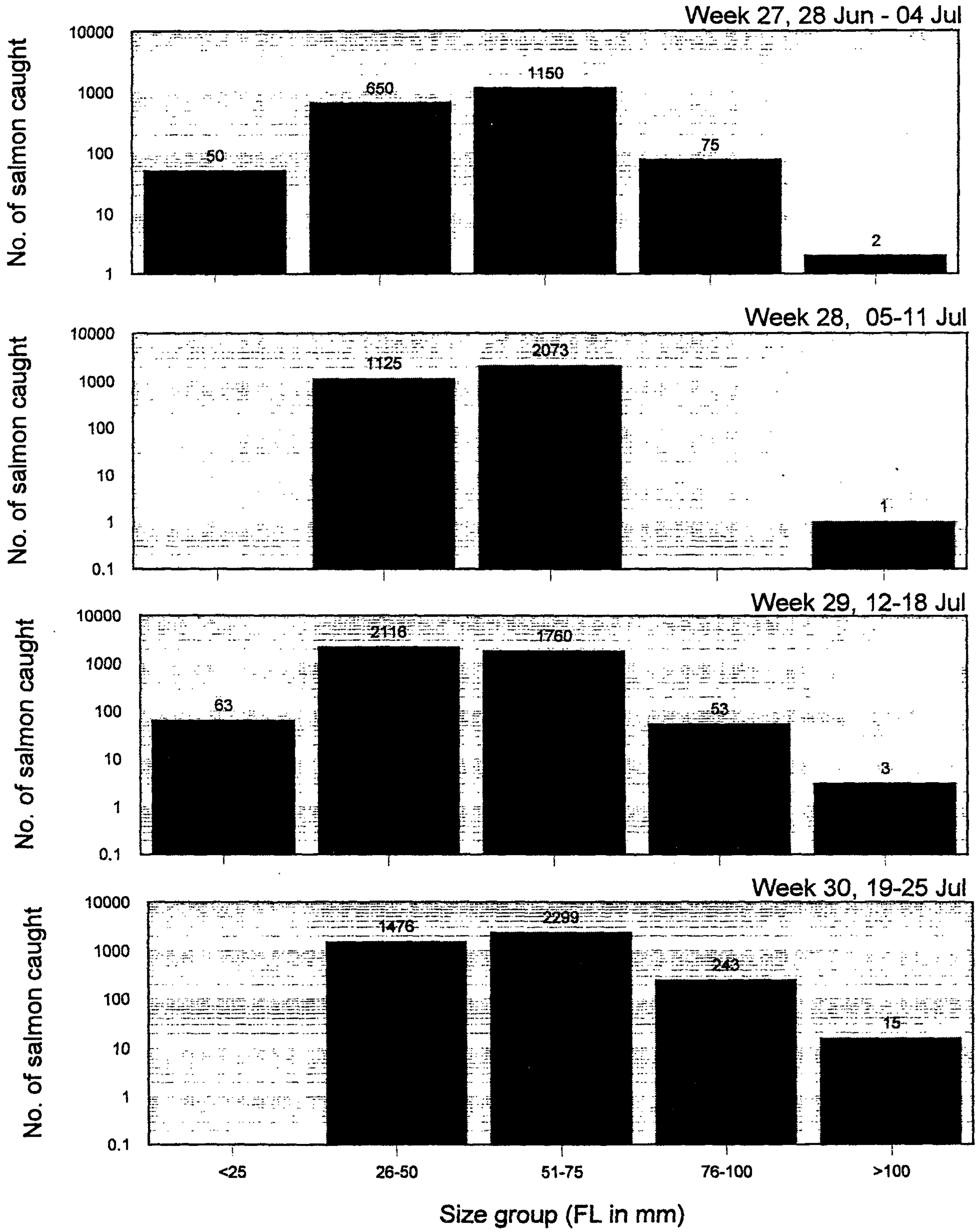

Figure 4. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 28 June - 25 July, 1998.

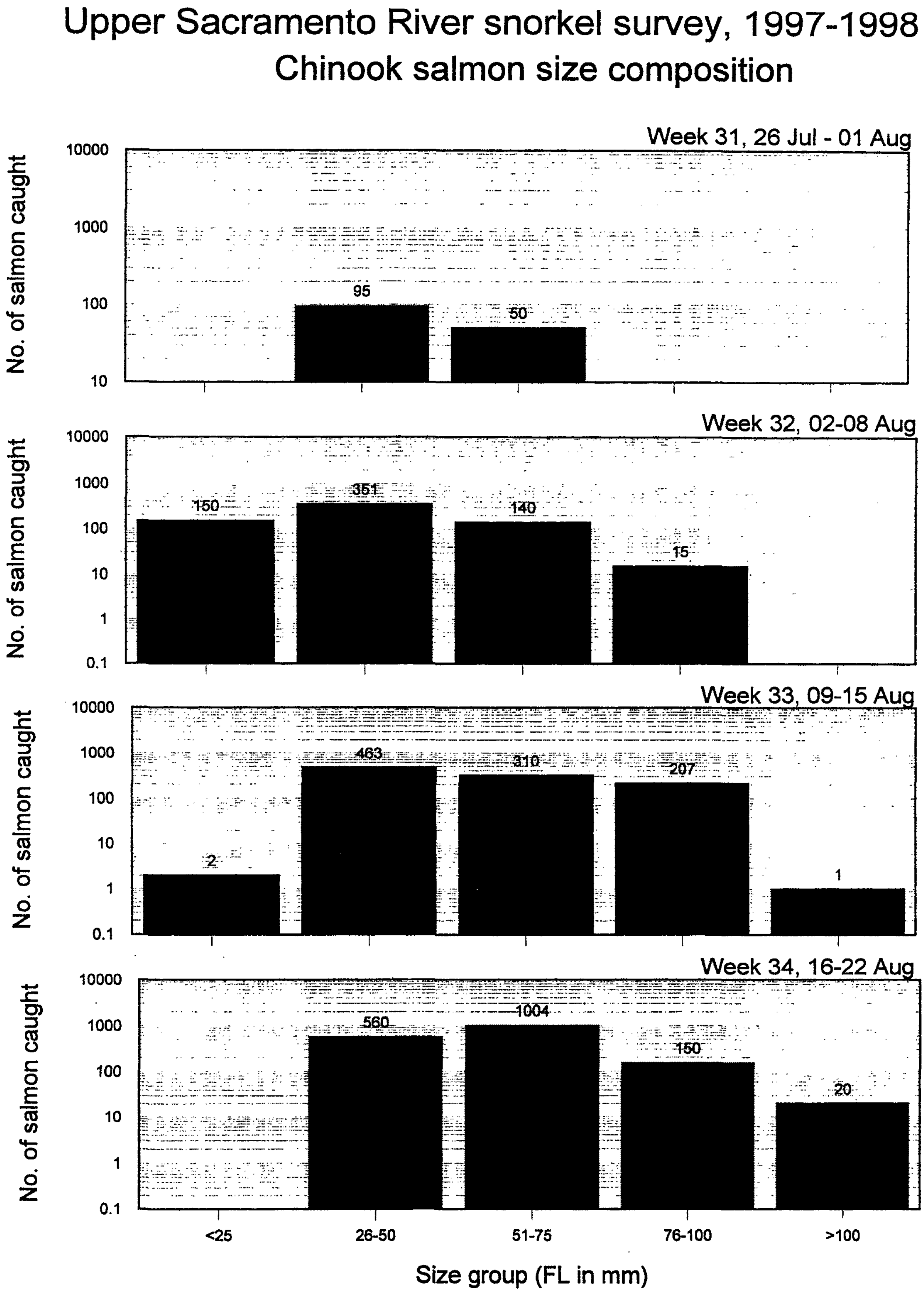

Figure 5. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 26 July - 22 August, 1998.

Upper Sacramento River snorkel survey, 1997-1998
Chinook salmon size composition

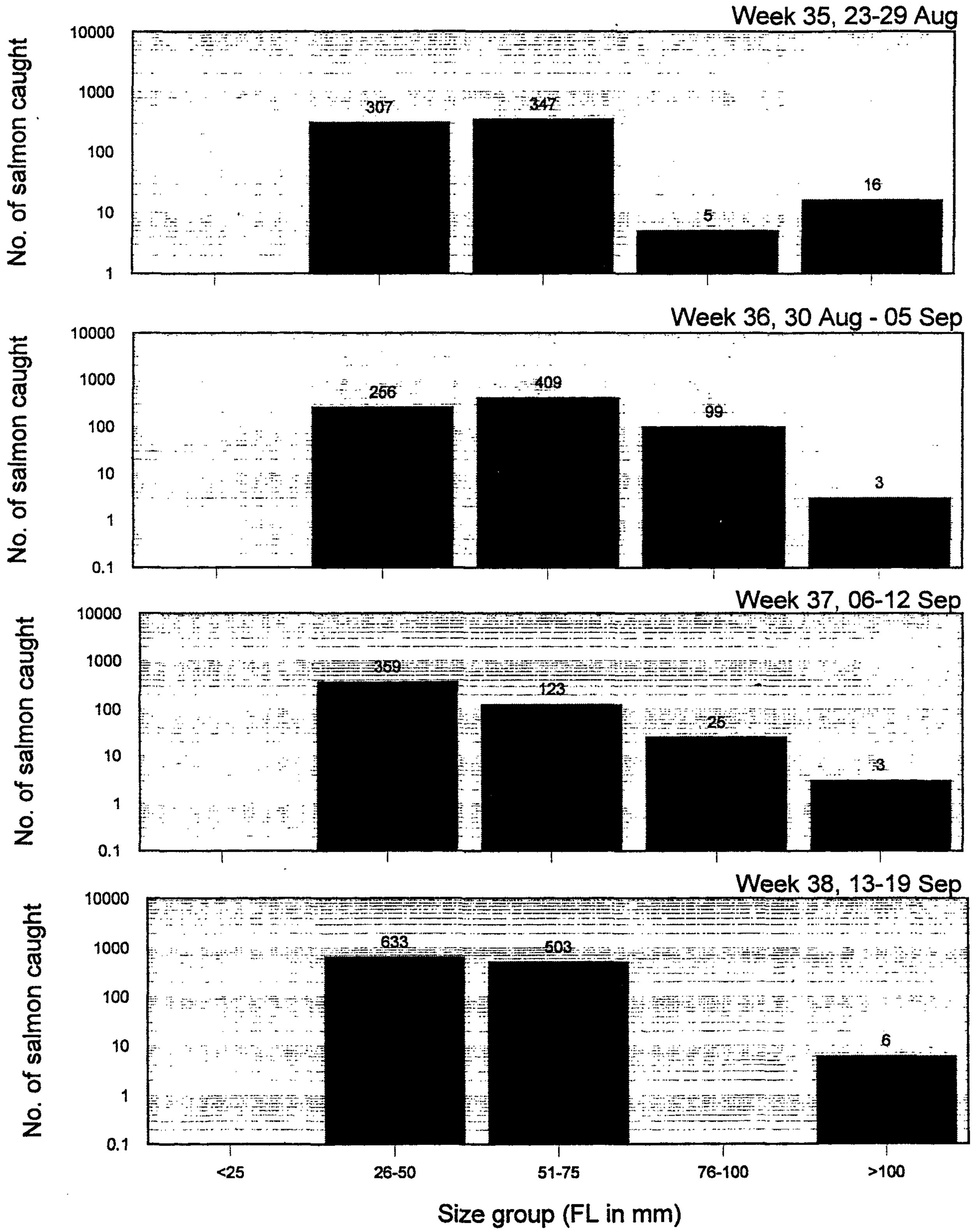

Figure 6. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 23 August - 19 September, 1998.

Upper Sacramento River snorkel survey, 1997-1998
Chinook salmon size composition

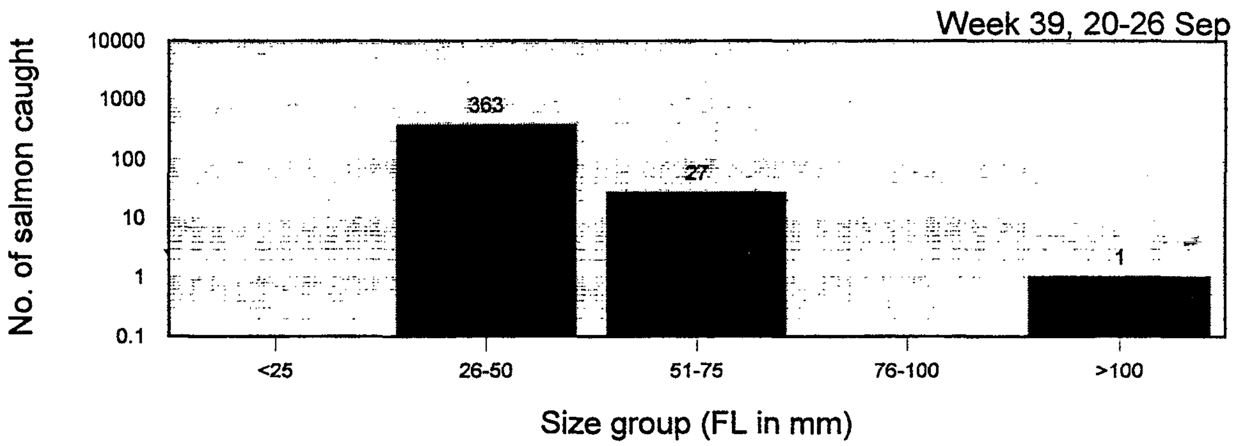

Figure 7. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 20-26 September, 1998.

Upper Sacramento River snorkel survey, June 1998
Chinook salmon habitat use distribution

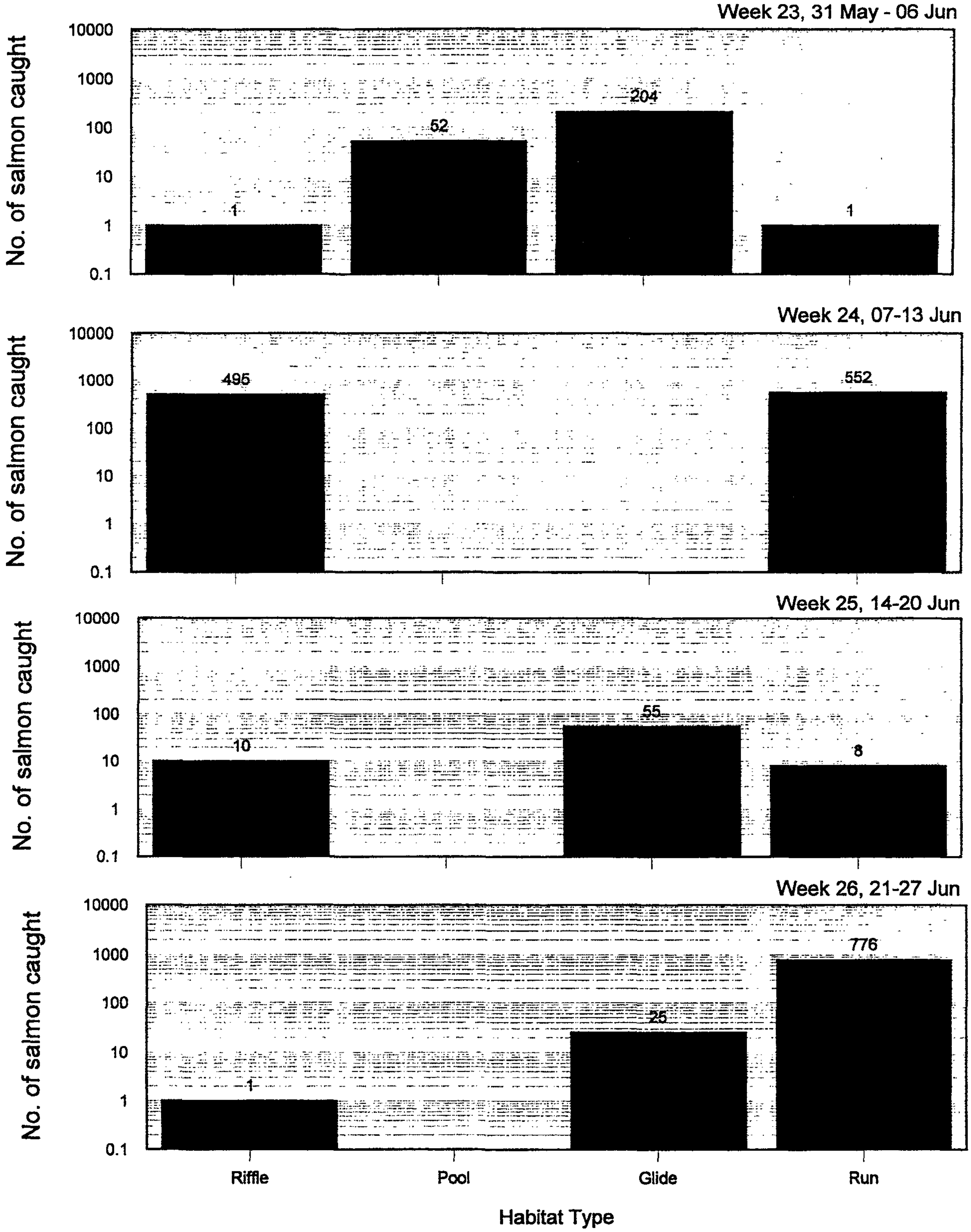

Figure 8. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 31 May - 27 June, 1998.

Upper Sacramento River snorkel survey, July 1998
Chinook salmon habitat use distribution

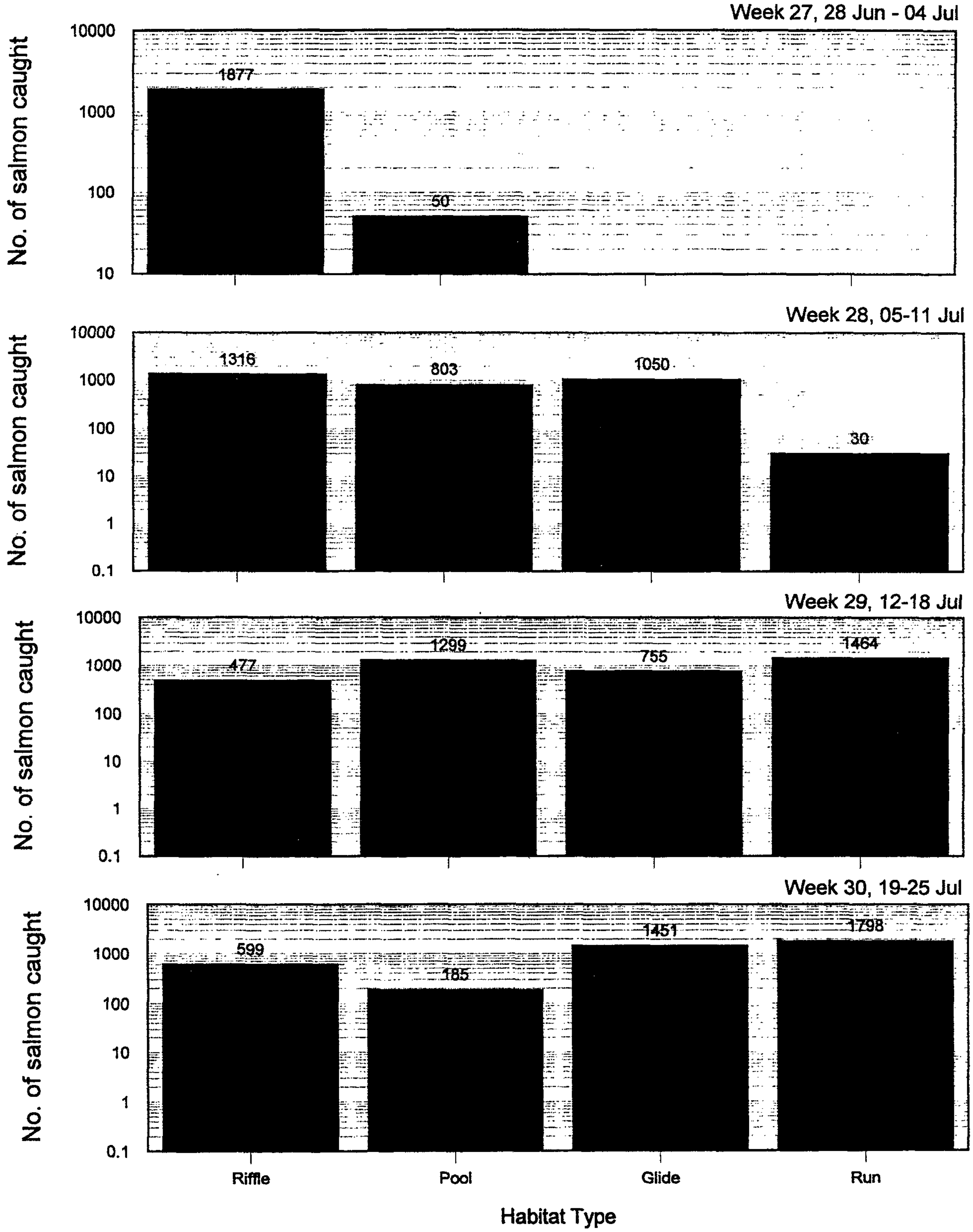

Figure 9. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 28 June - 25 July, 1998.

Upper Sacramento River snorkel survey, August 1998
Chinook salmon habitat use distribution

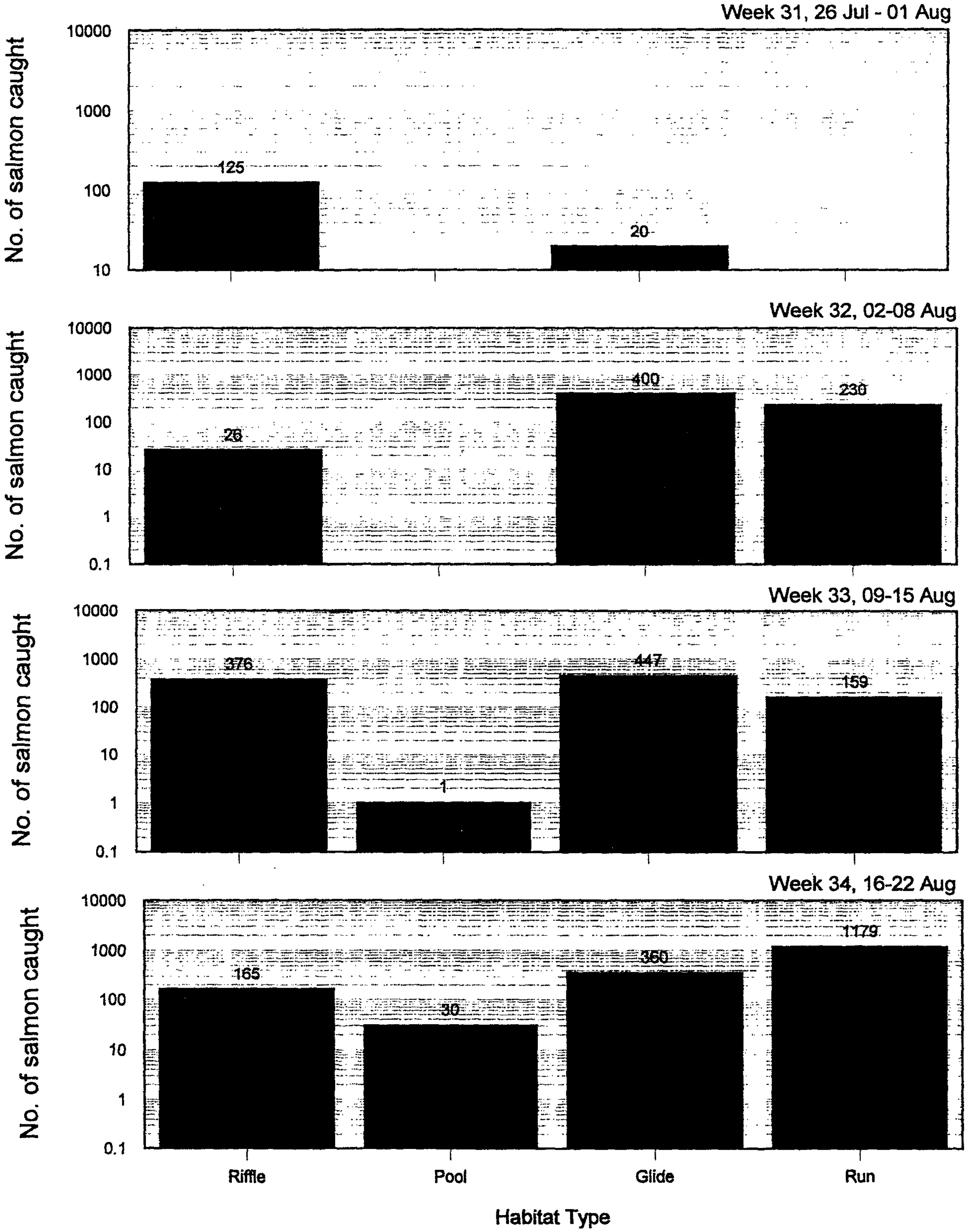

Figure 10. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 26 July - 22 August, 1998.

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Upper Sacramento River snorkel survey, September 1998
Chinook salmon habitat use distribution

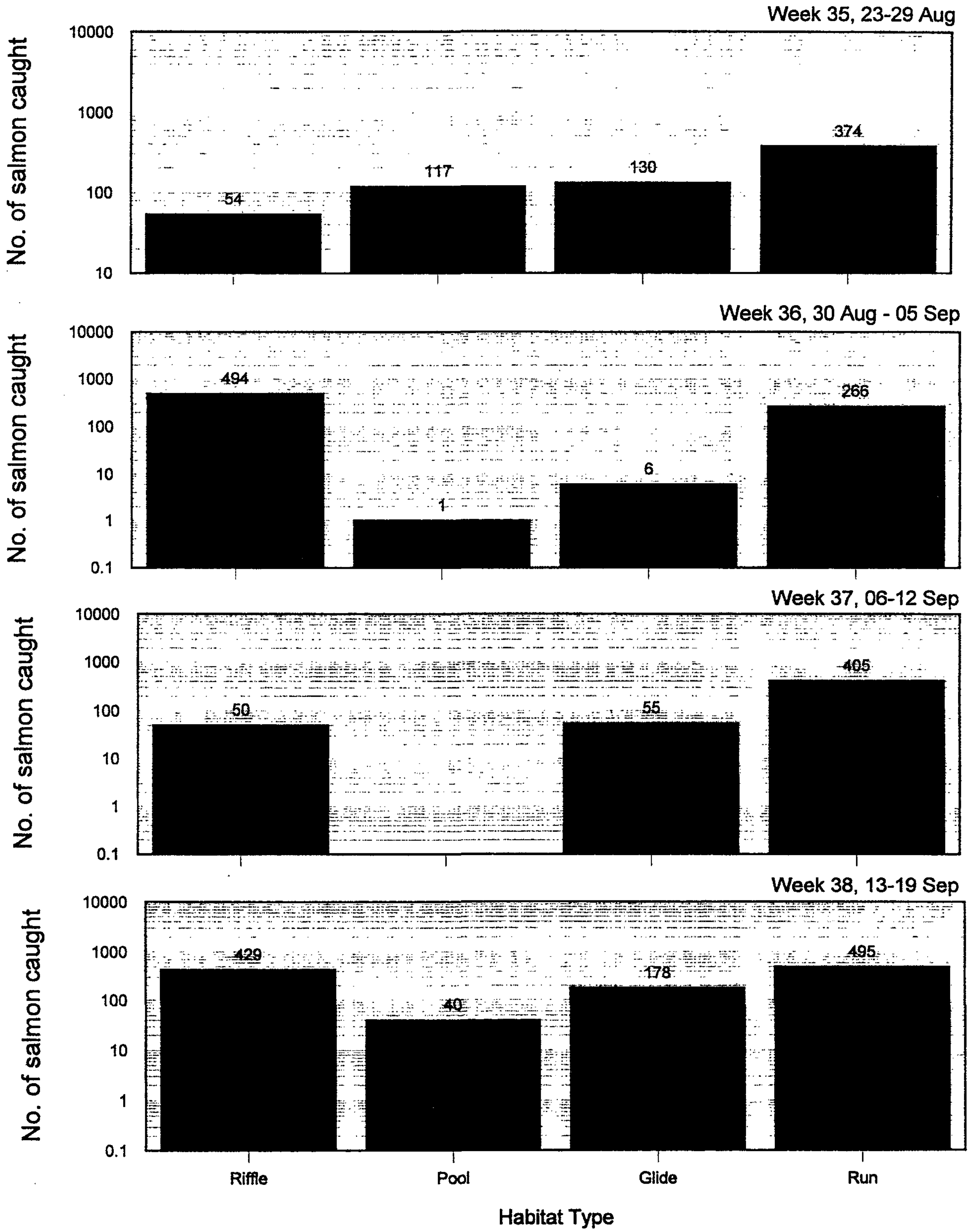


Figure 11. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 23 August - 19 September, 1998.

Upper Sacramento River snorkel survey, September 1998
Chinook salmon habitat use distribution

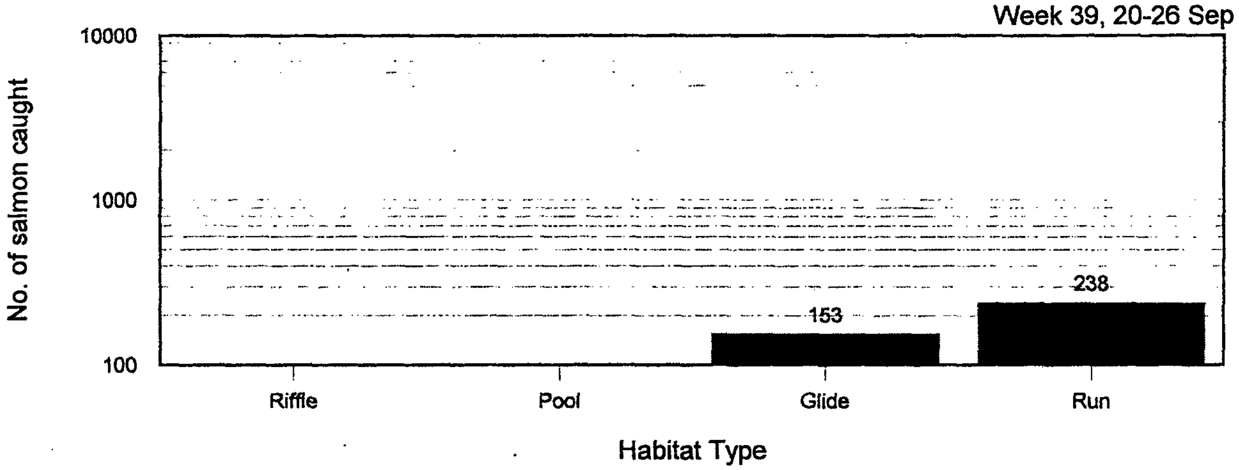


Figure 12. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 20-26 September, 1998.

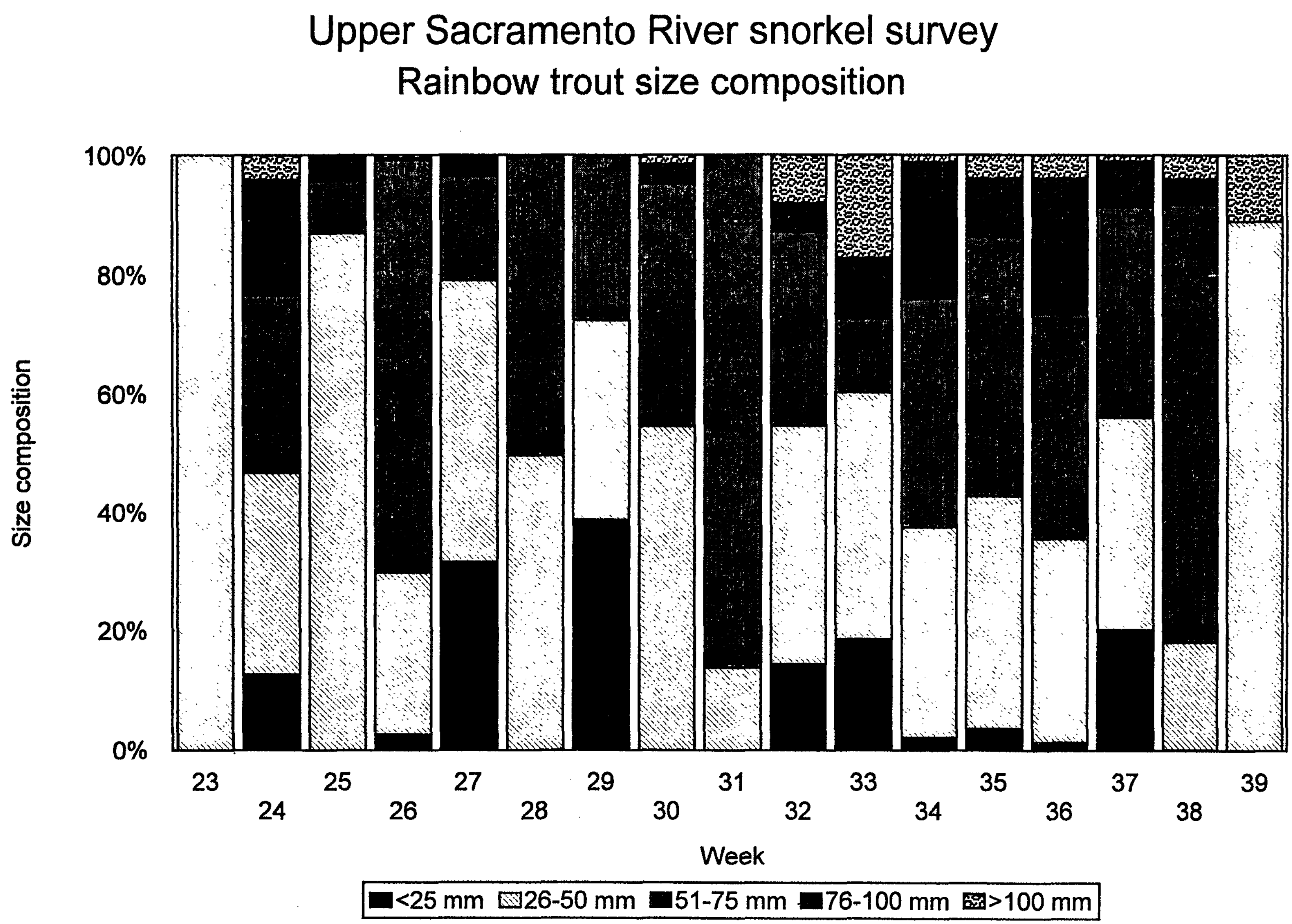


Figure 13. Weekly size composition of steelhead observed during the upper Sacramento River snorkel survey, October 1997 - September 1998. No sites were sampled Week 40 through Week 22.

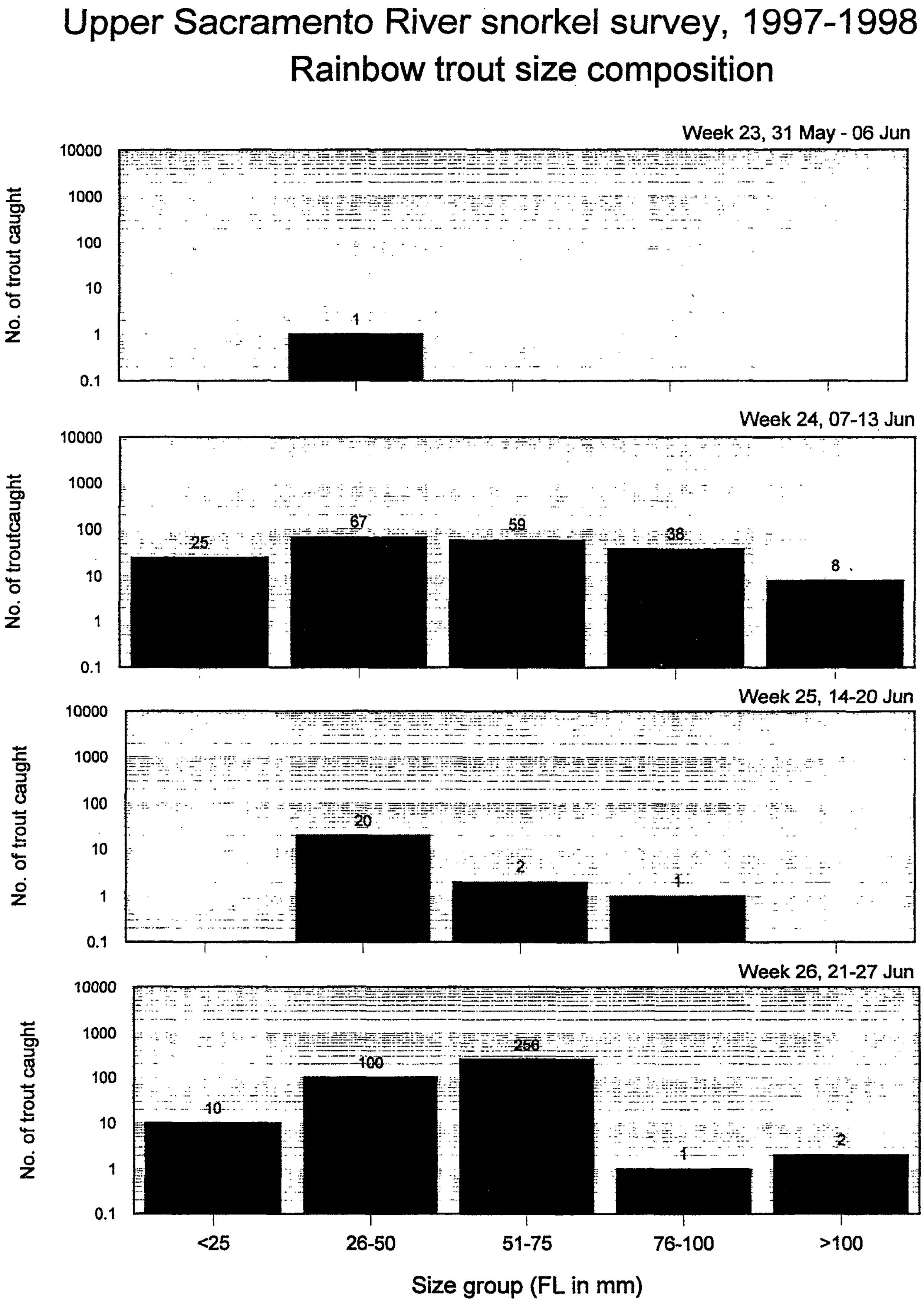


Figure 14. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 31 May - 27 June, 1998.

Upper Sacramento River snorkel survey, 1997-1998
Rainbow trout size composition

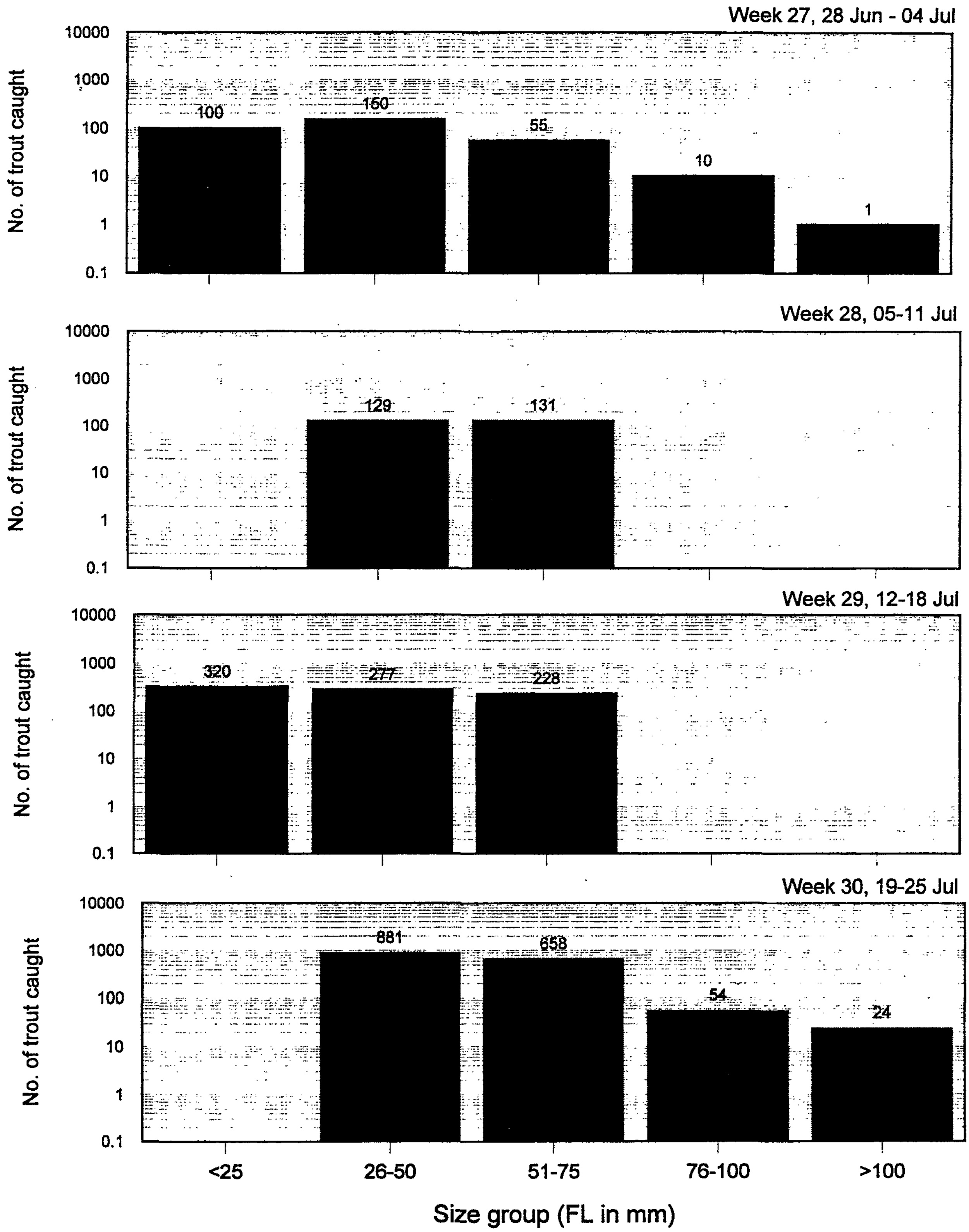


Figure 15. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 28 June - 25 July, 1998.

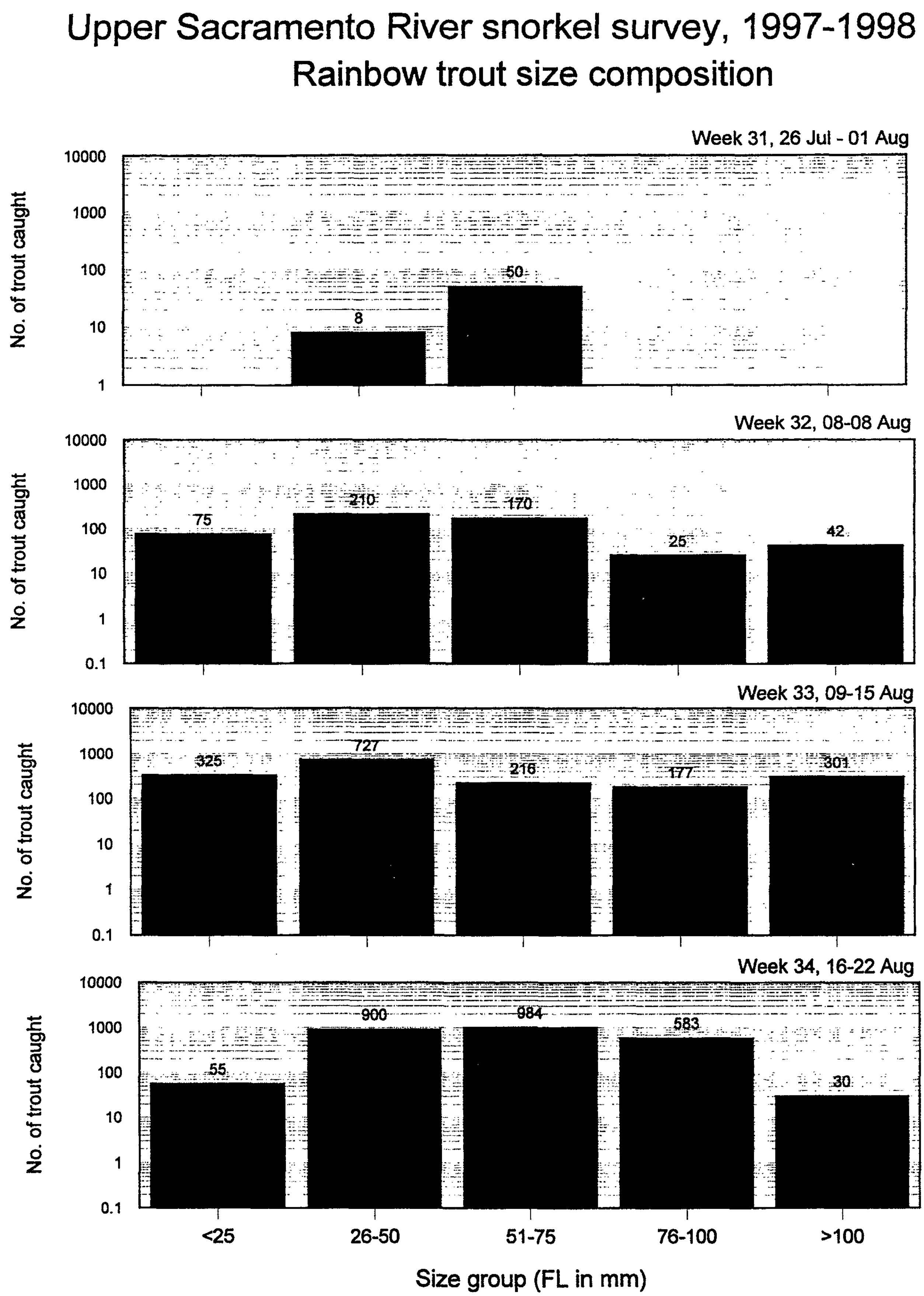


Figure 16. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 26 July - 22 August, 1998.

Upper Sacramento River snorkel survey, 1997-1998
Rainbow trout size composition

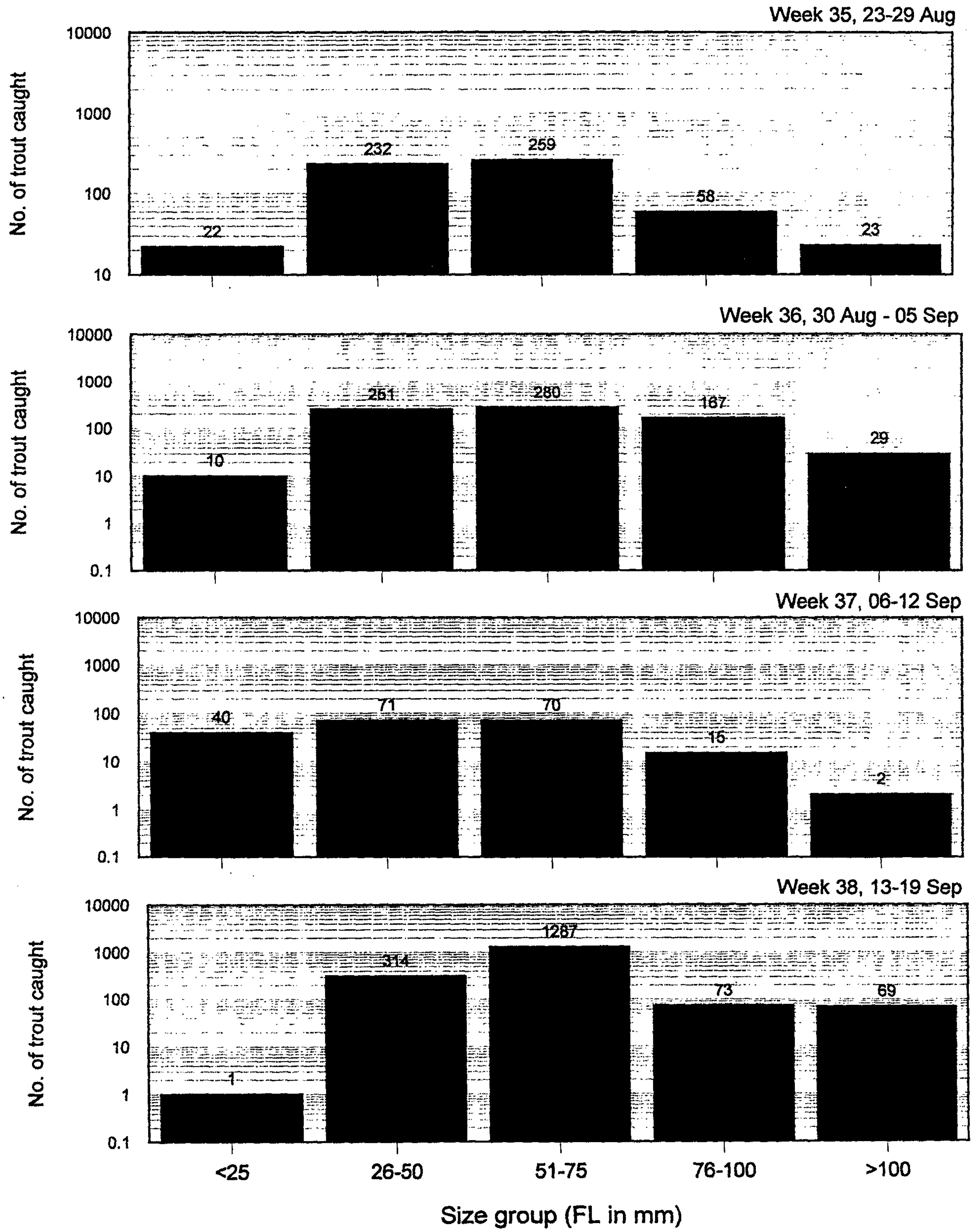


Figure 17. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 23 August - 19 September, 1998.

Upper Sacramento River snorkel survey, 1997-1998
Rainbow trout size composition

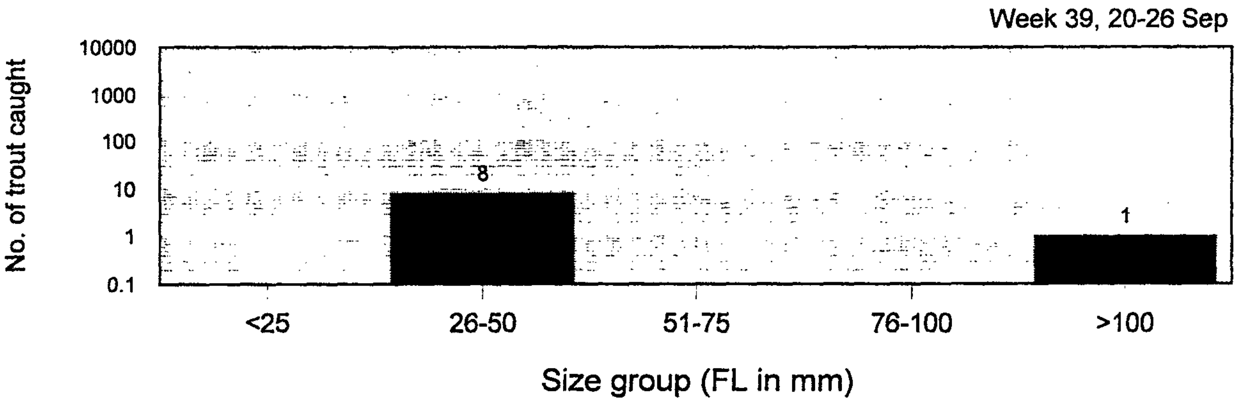


Figure 18. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 20-26 September, 1998.

Upper Sacramento River snorkel survey, June, 1998
Rainbow trout habitat use distribution

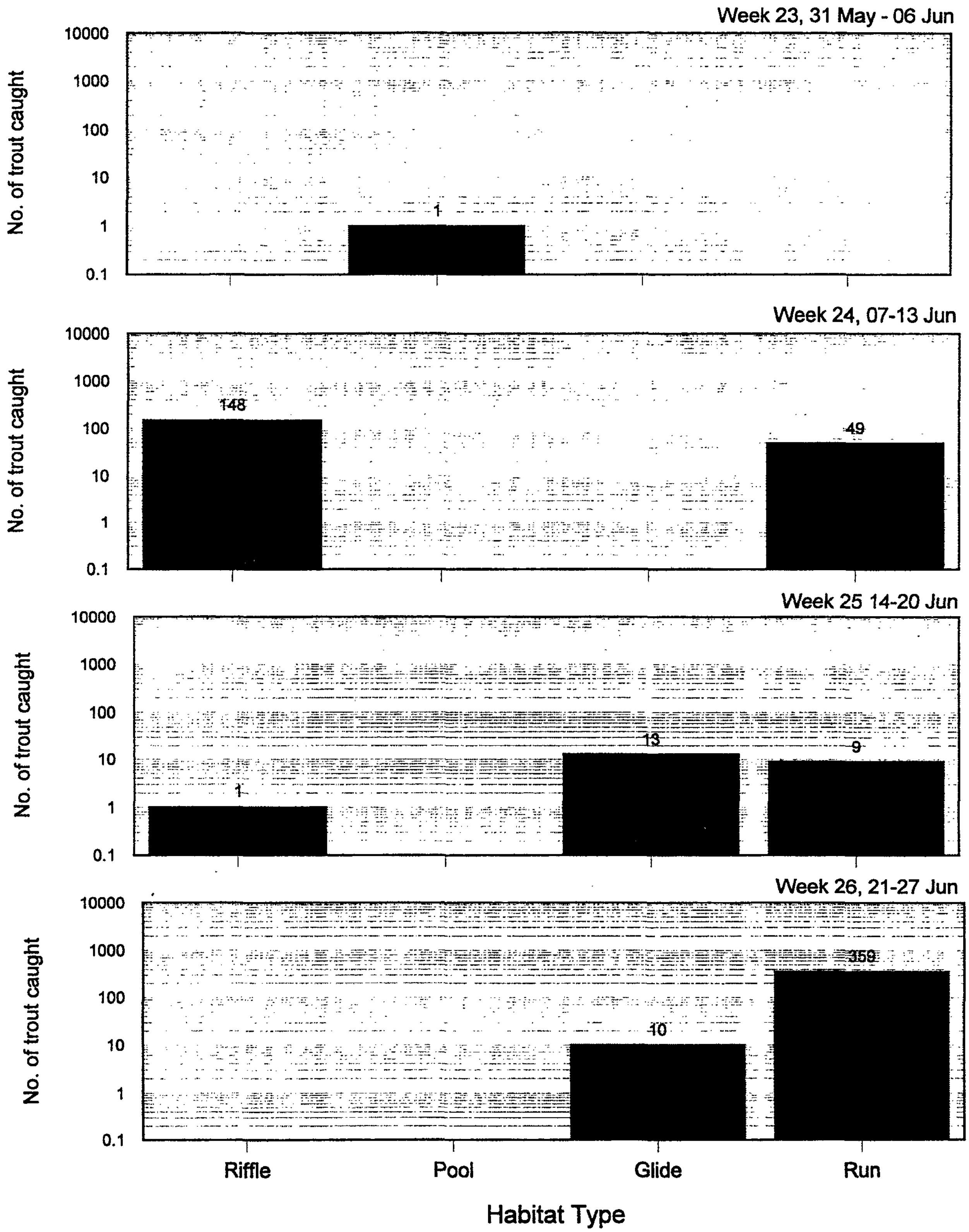


Figure 19. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 31 May - 27 June, 1998.

Upper Sacramento River snorkel survey, July, 1998
Rainbow trout habitat use distribution

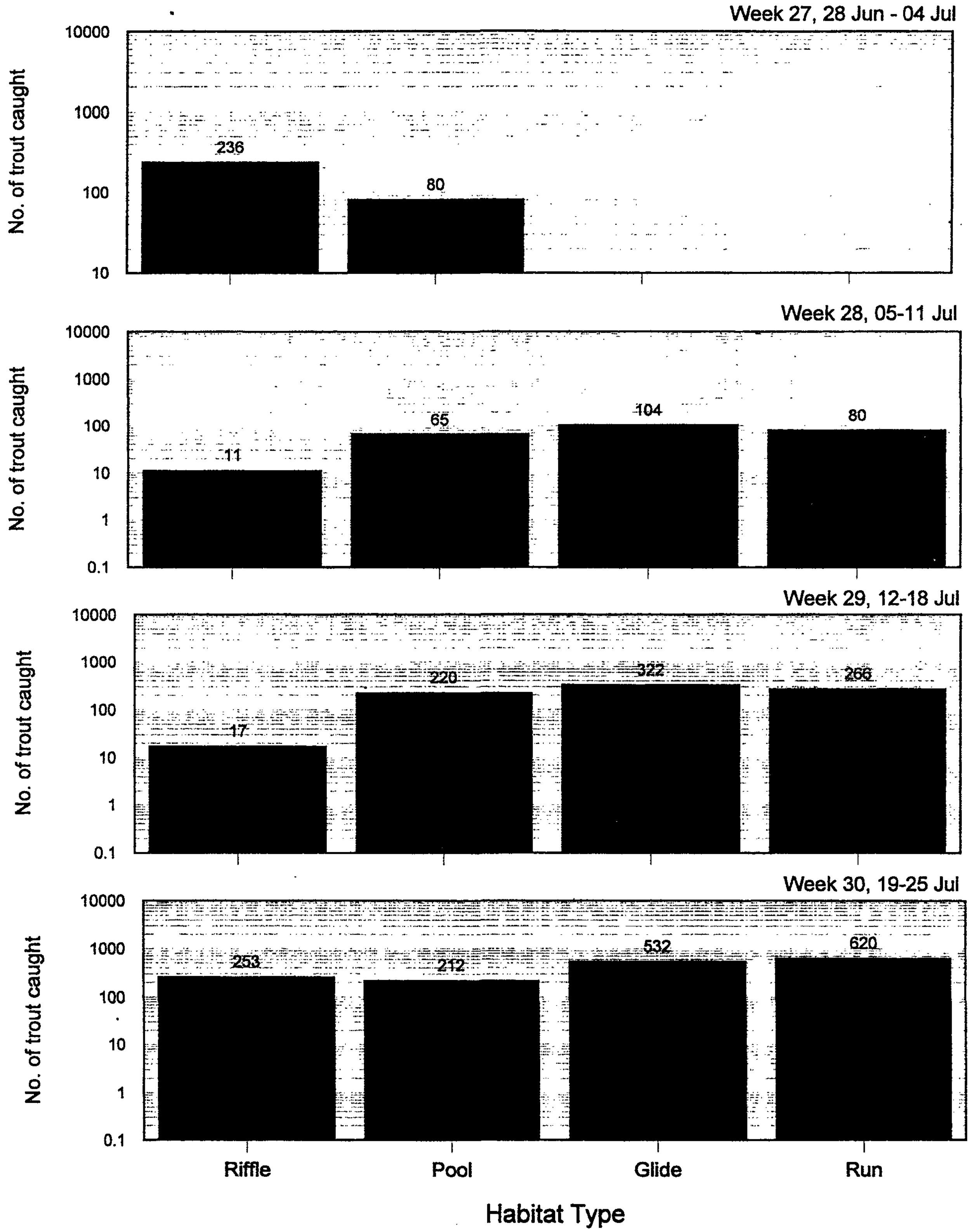


Figure 20. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 28 June - 25 July, 1998.

Upper Sacramento River snorkel survey, August, 1998
Rainbow trout habitat use distribution

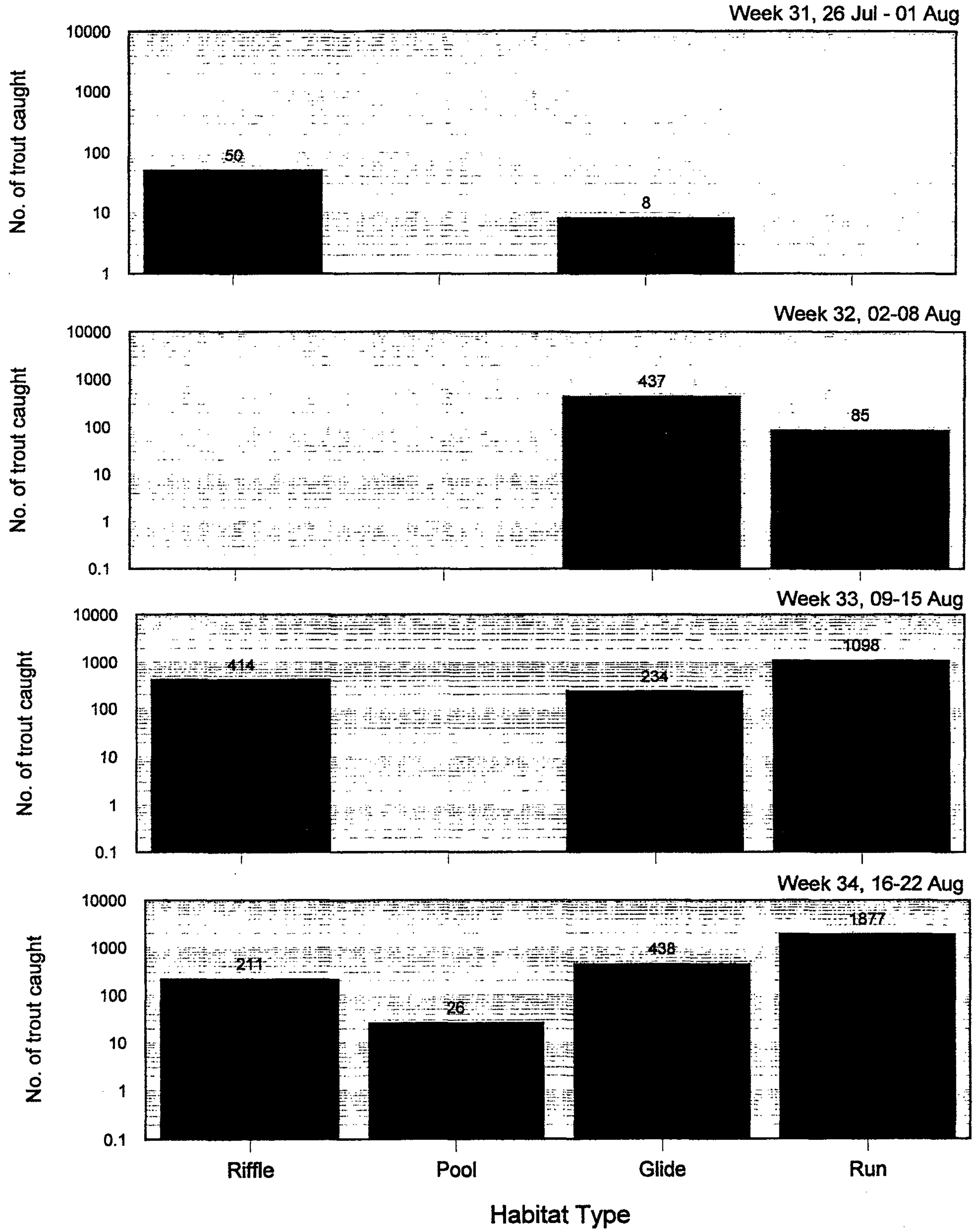


Figure 21. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 26 July - 22 August, 1998.

Upper Sacramento River snorkel survey, September, 1998
Rainbow trout habitat use distribution

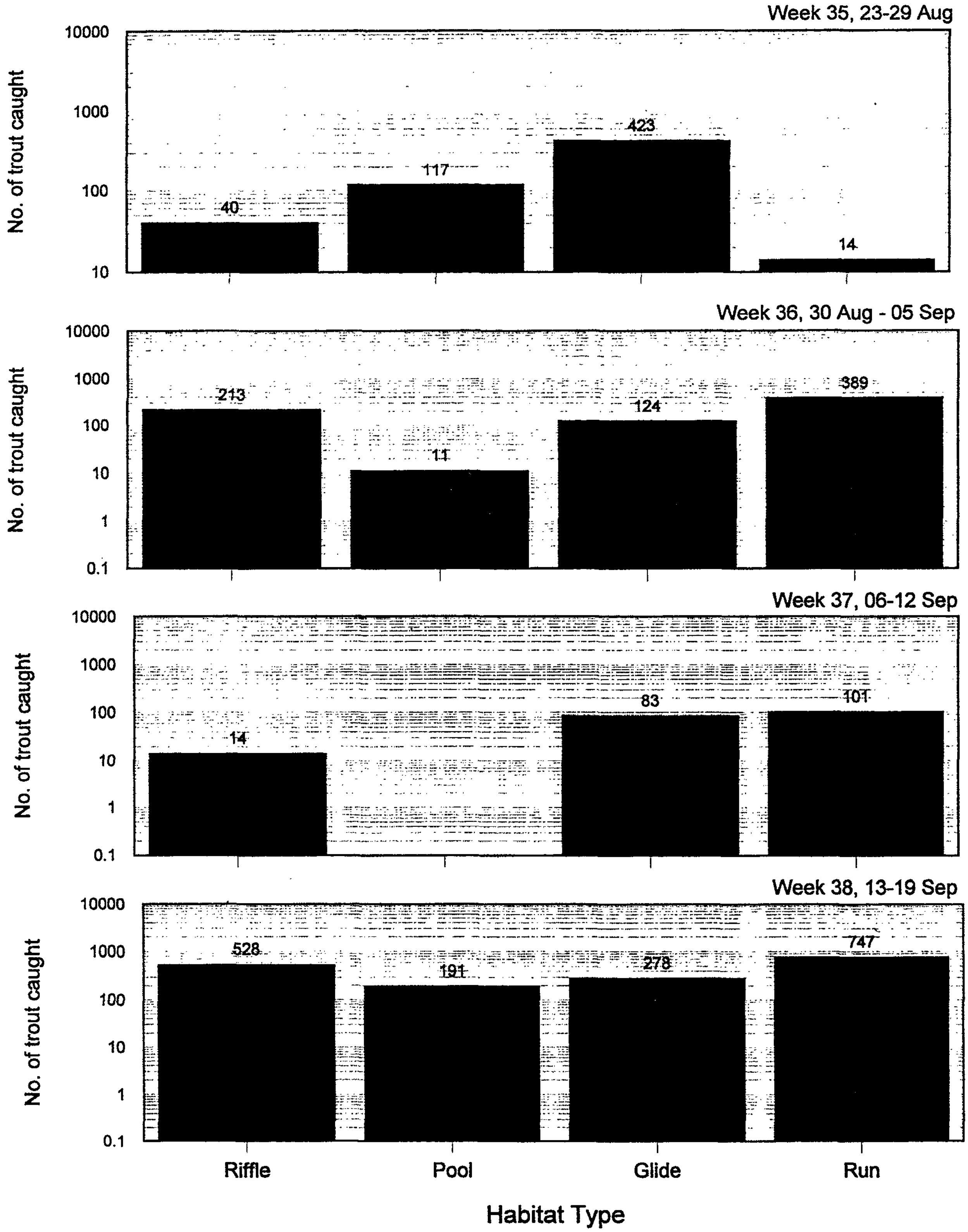


Figure 22. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 23 August - 19 September, 1998.

Upper Sacramento River snorkel survey, September, 1998
Rainbow trout habitat use distribution

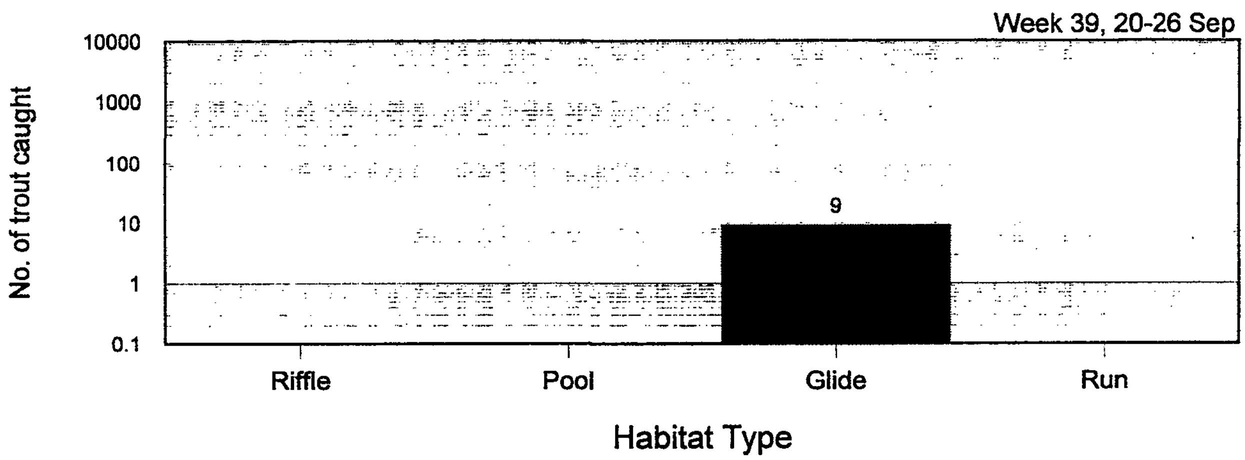


Figure 23. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 20-26 September, 1998.

Upper Sacramento River seining survey
Chinook salmon fork length distribution

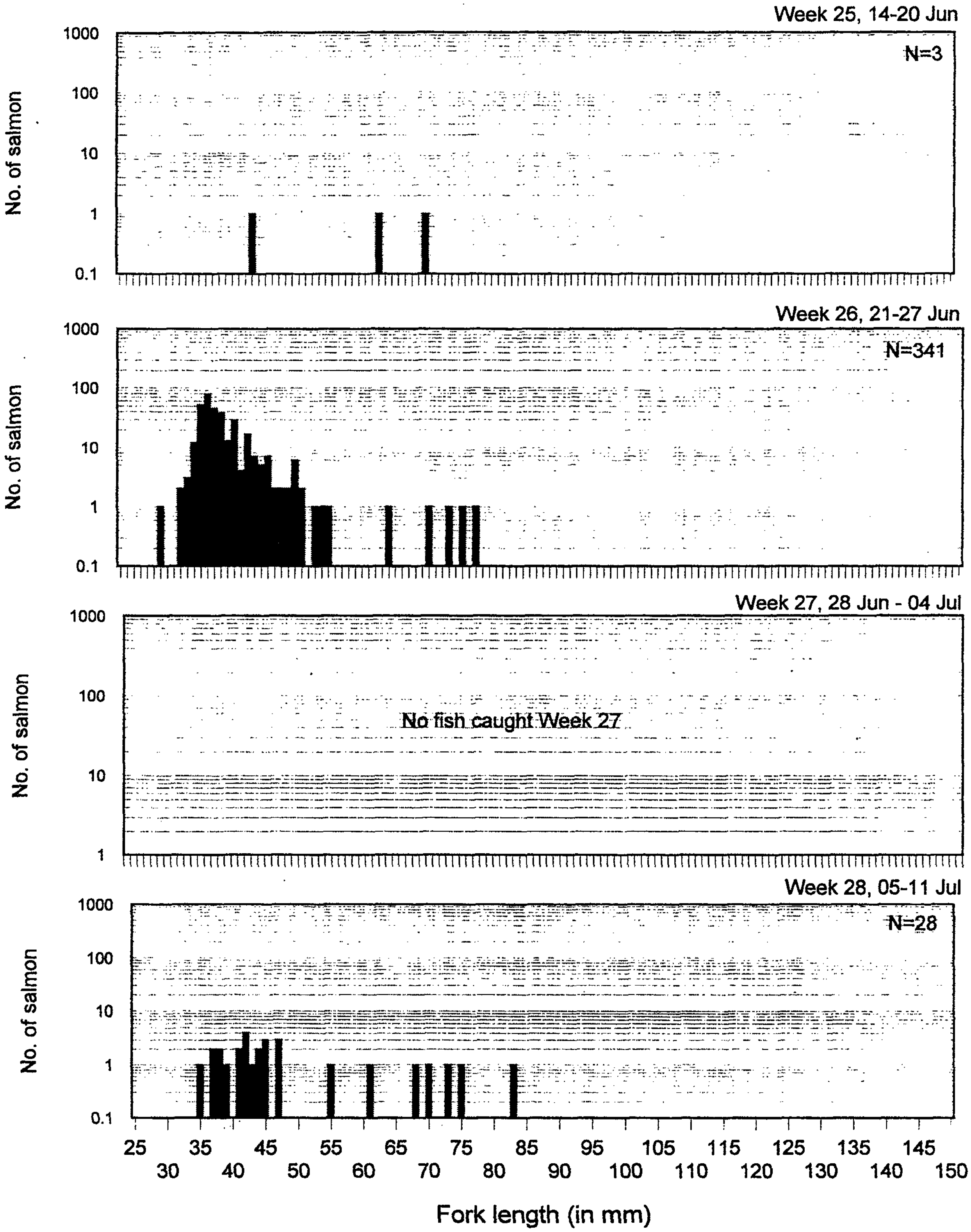


Figure 24. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 14 June - 11 July, 1998.

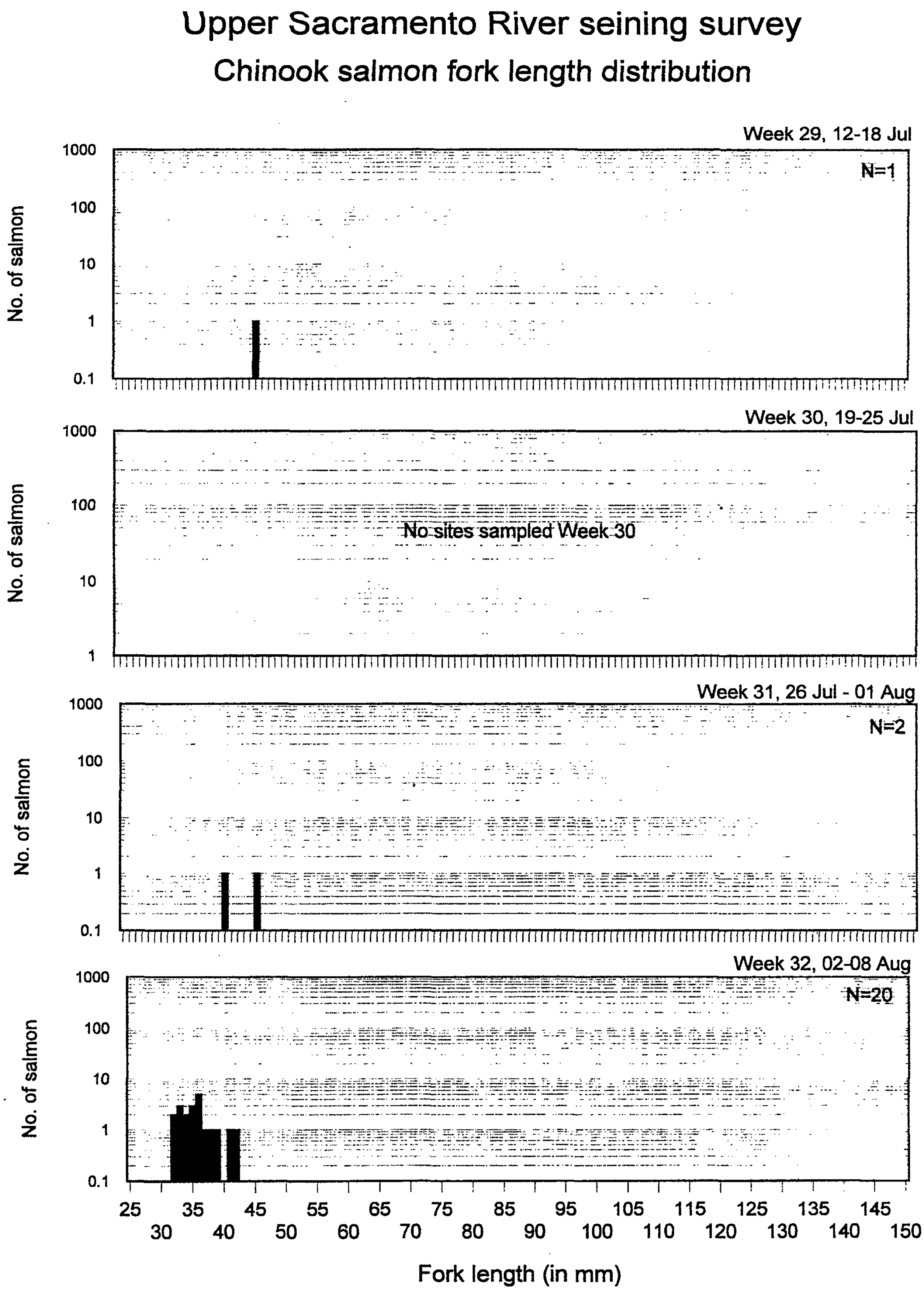


Figure 25. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 12 July - 08 August, 1998.

Upper Sacramento River seining survey

Chinook salmon fork length distribution

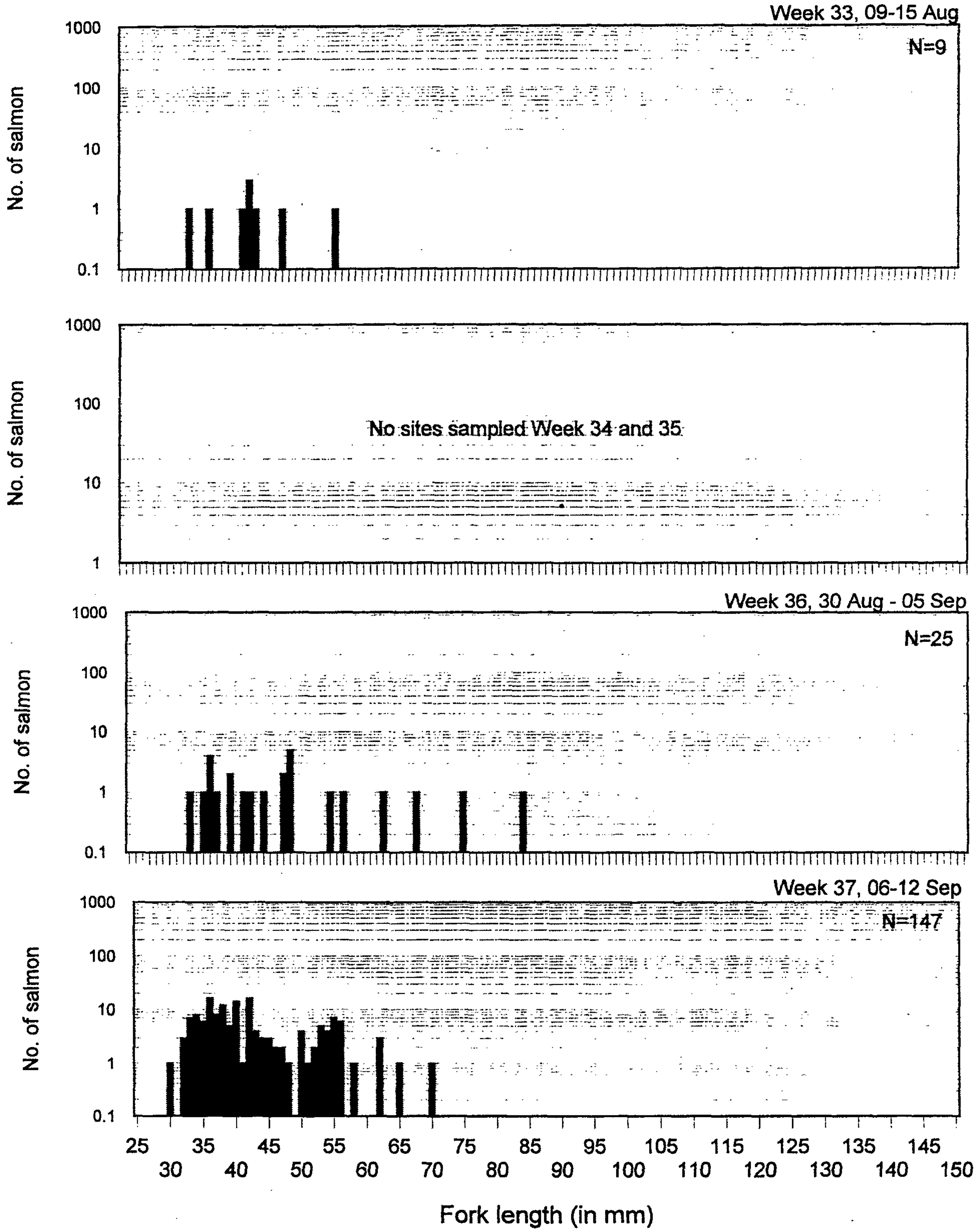


Figure 26. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 09 August - 12 September, 1998.

Upper Sacramento River seining survey
Rainbow trout fork length distribution

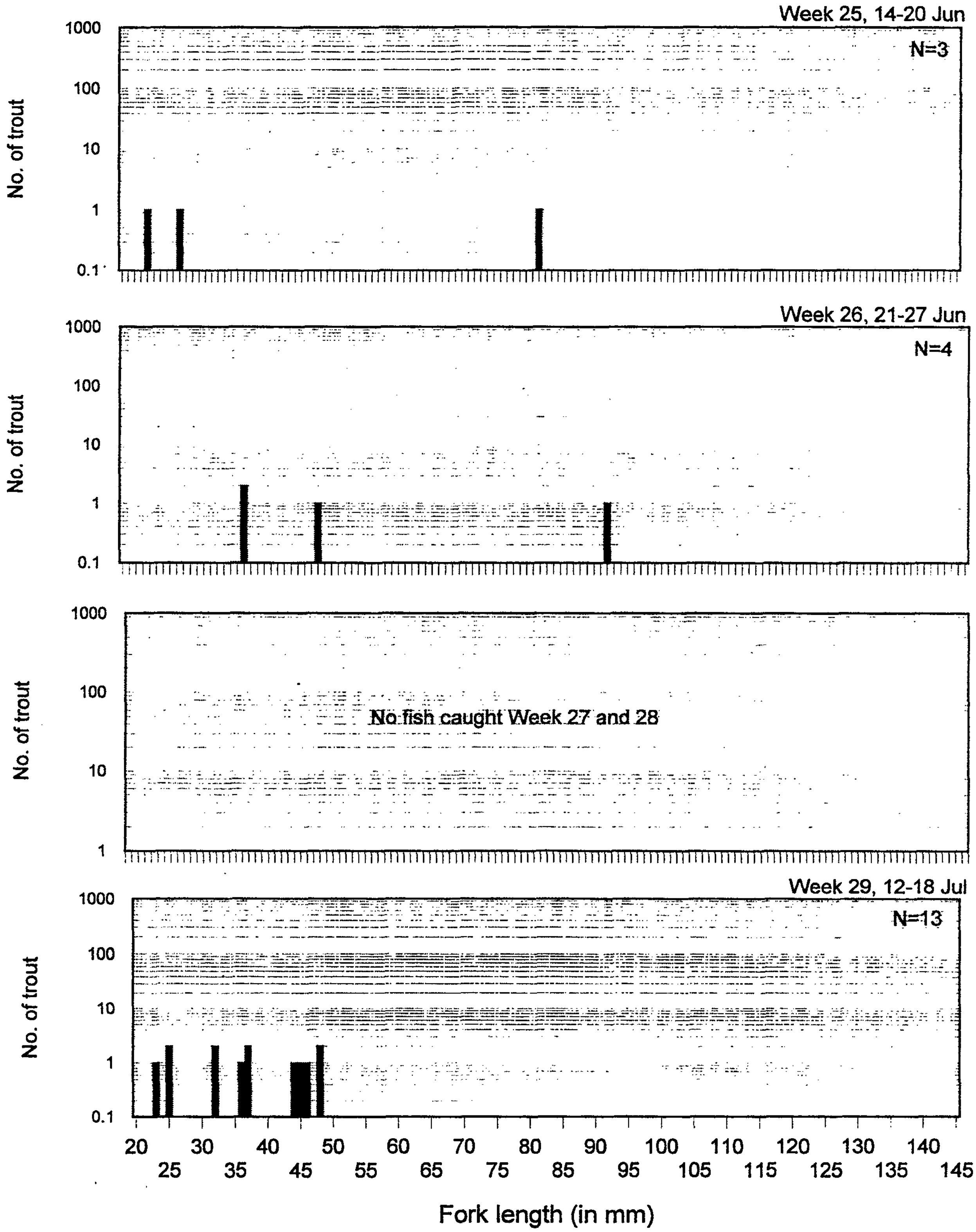


Figure 27. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 14 June - 18 July, 1998.

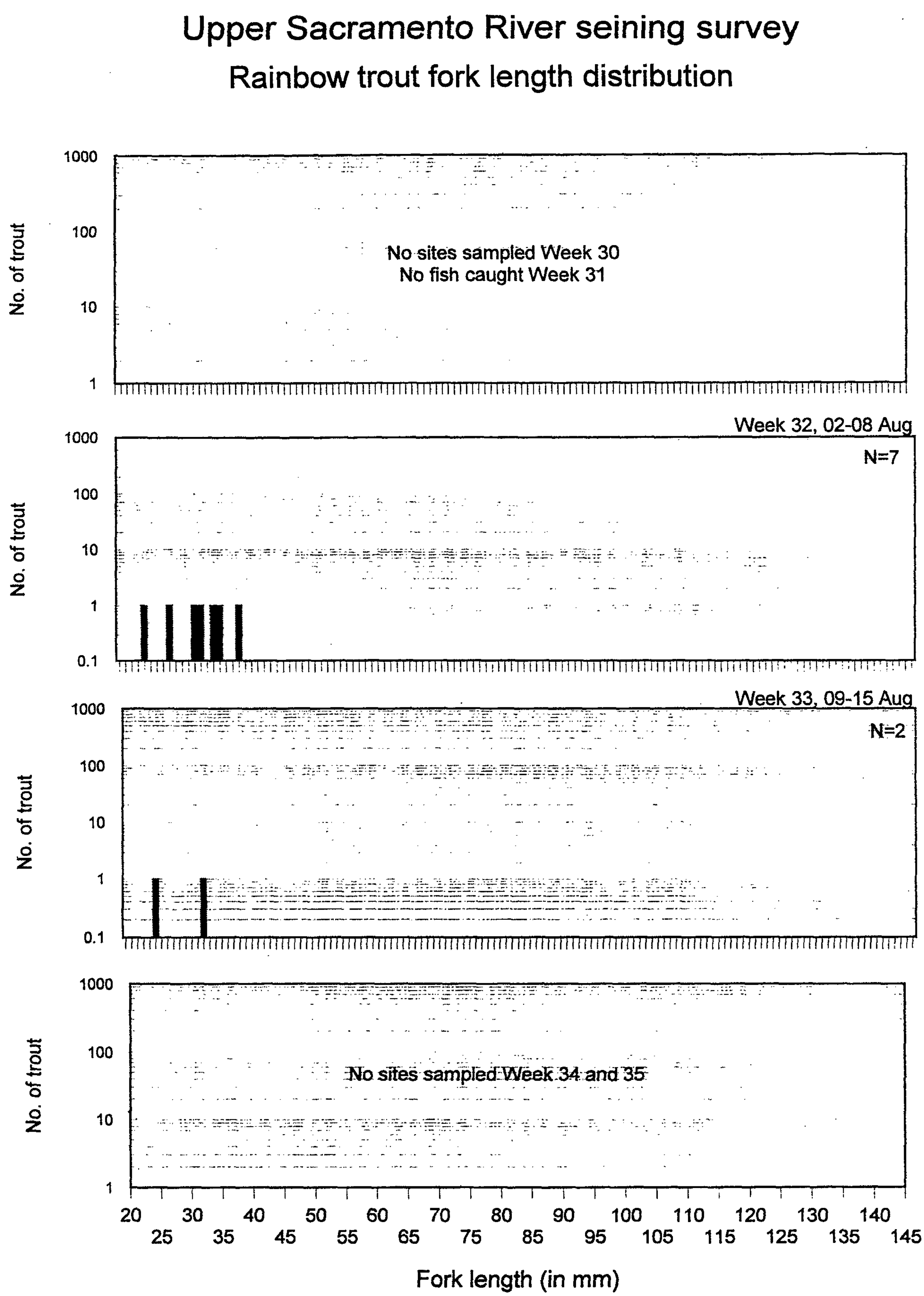


Figure 28. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 19 July - 29 August, 1998.

D—025542

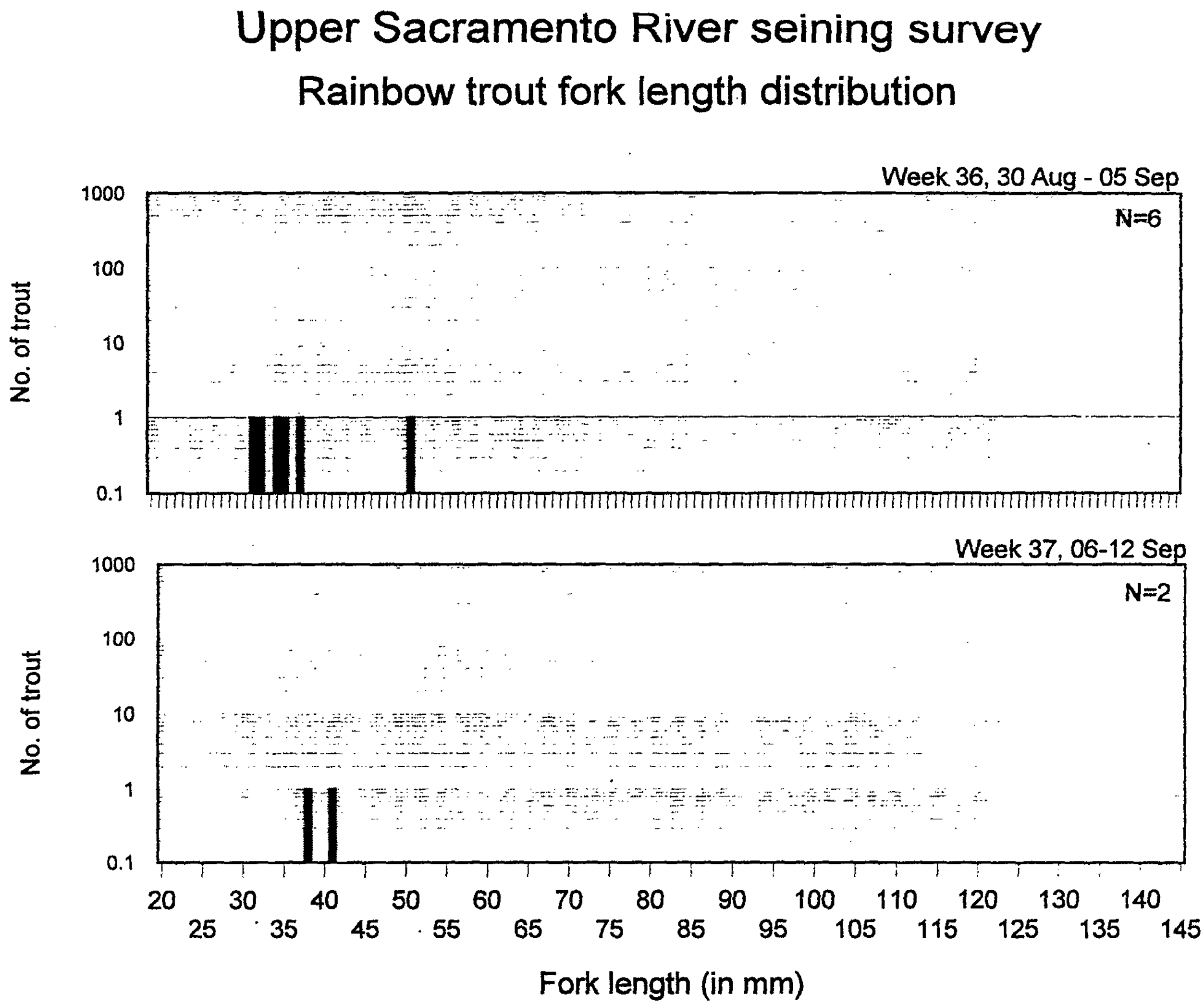


Figure 29. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 30 August - 12 September, 1998.

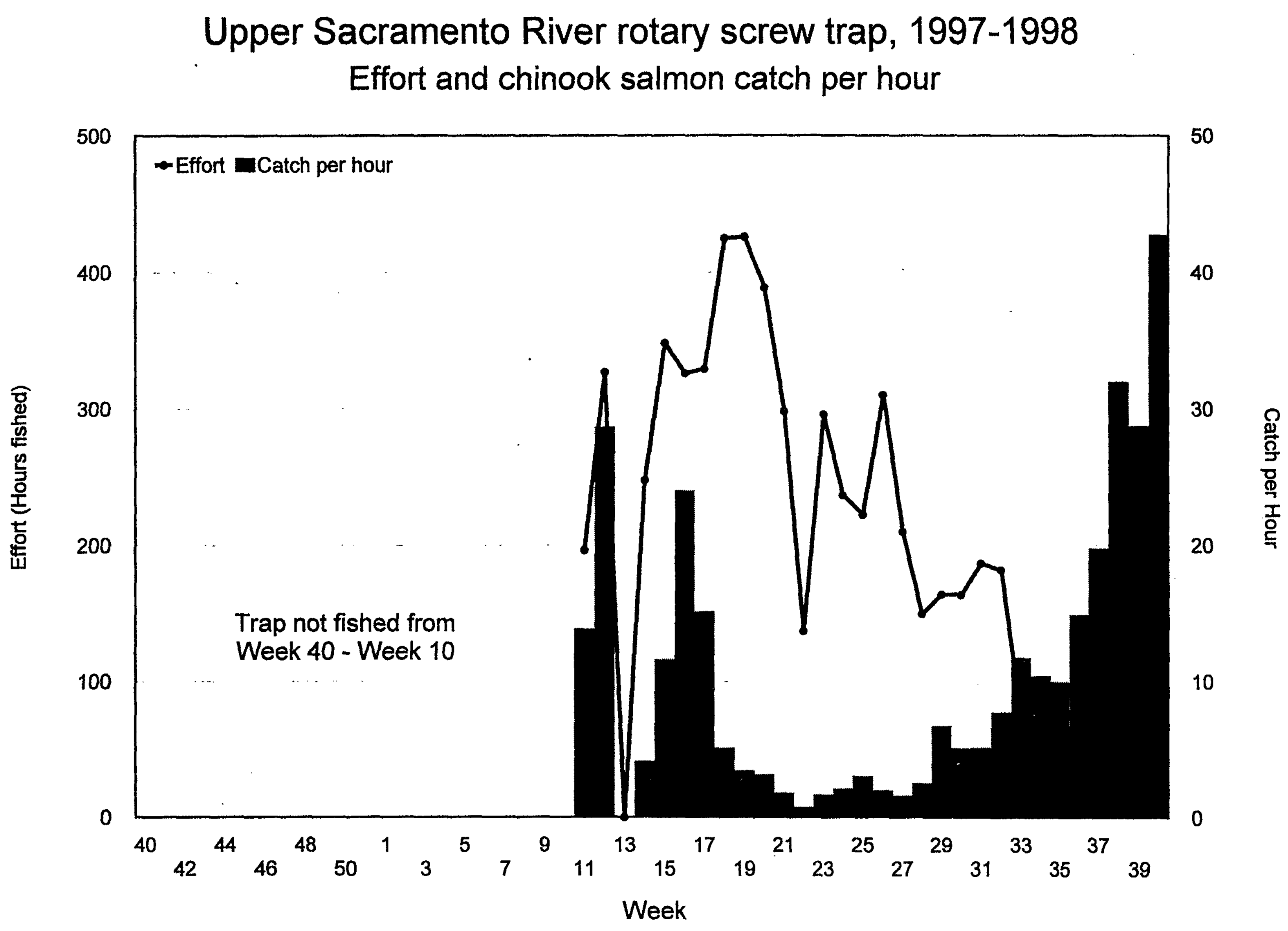


Figure 30. Weekly catch per hour of chinook salmon and hours fished by rotary screw trap in the upper Sacramento River, 01 October, 1997 - September 30, 1998.

D-025544

D—025545

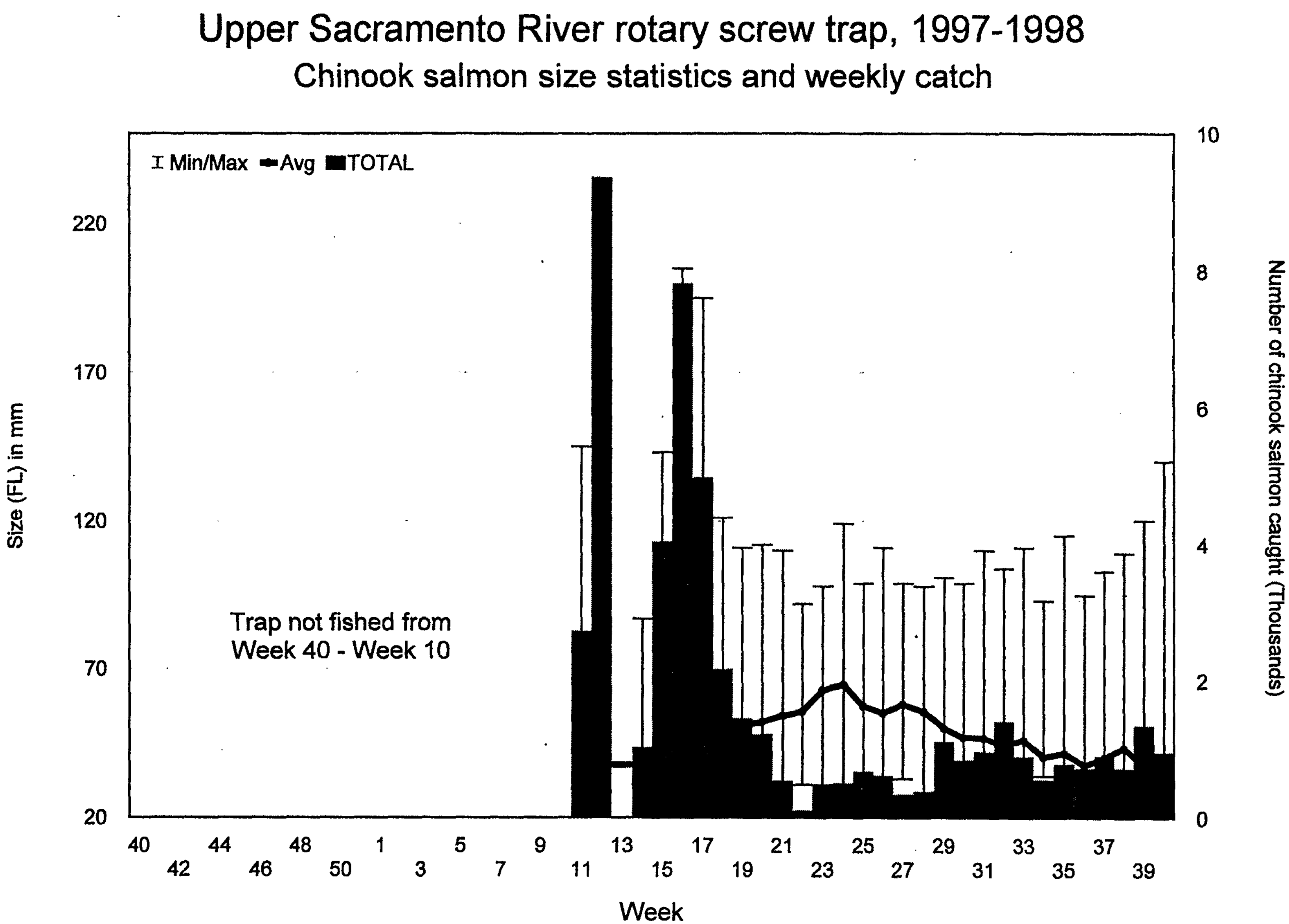


Figure 31. Chinook salmon mean fork length (minimum and maximum) and total caught by rotary screw trap in the upper Sacramento River, October 1997 - September 1998.

Upper Sacramento River rotary screw trap survey
Chinook salmon catch distribution by race

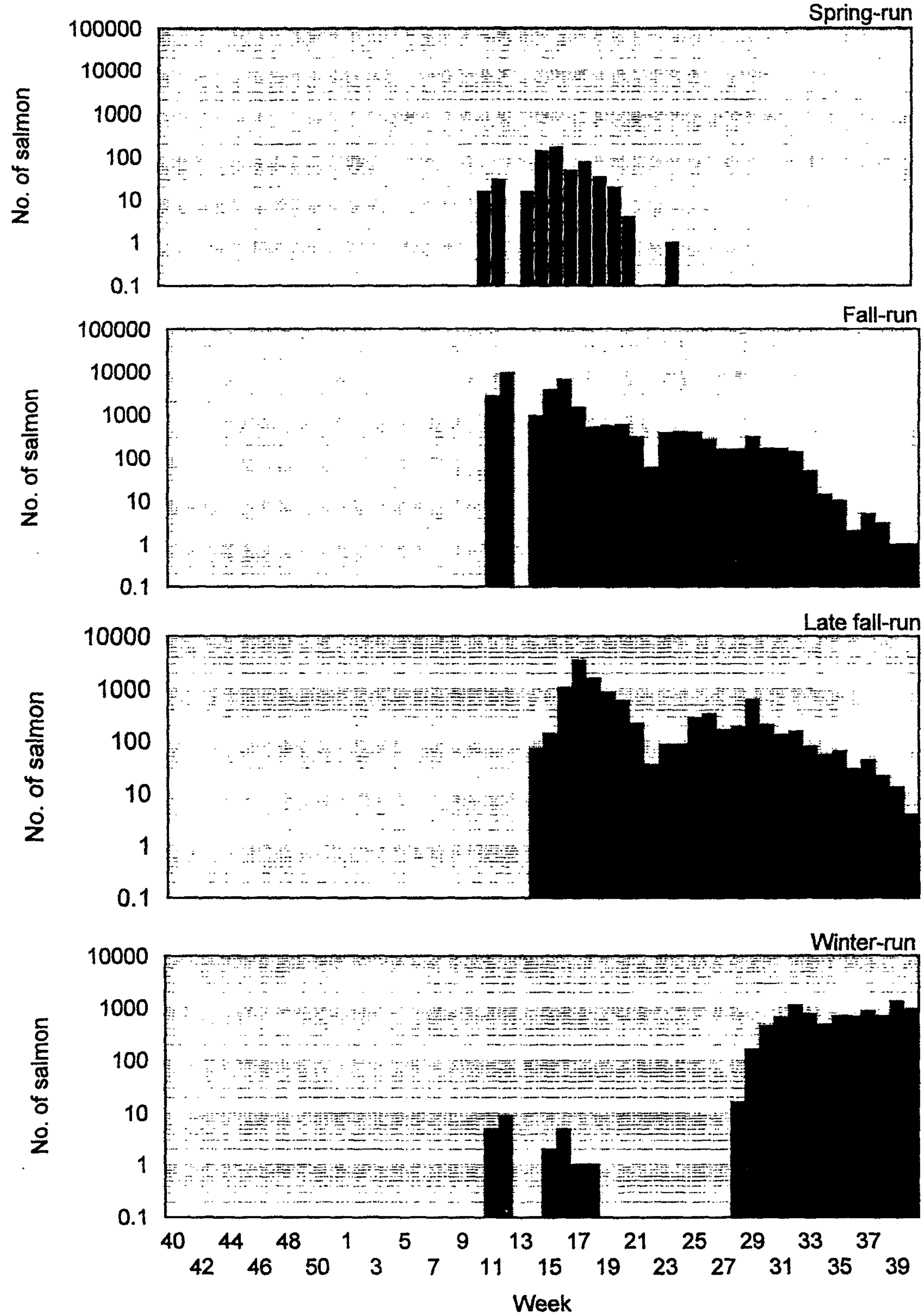


Figure 32. Catch distribution of chinook salmon races collected by rotary screw trap in the upper Sacramento River, 01 October, 1997 - 30 September, 1998.

Upper Sacramento River rotary screw trap survey
Chinook salmon size distribution by race

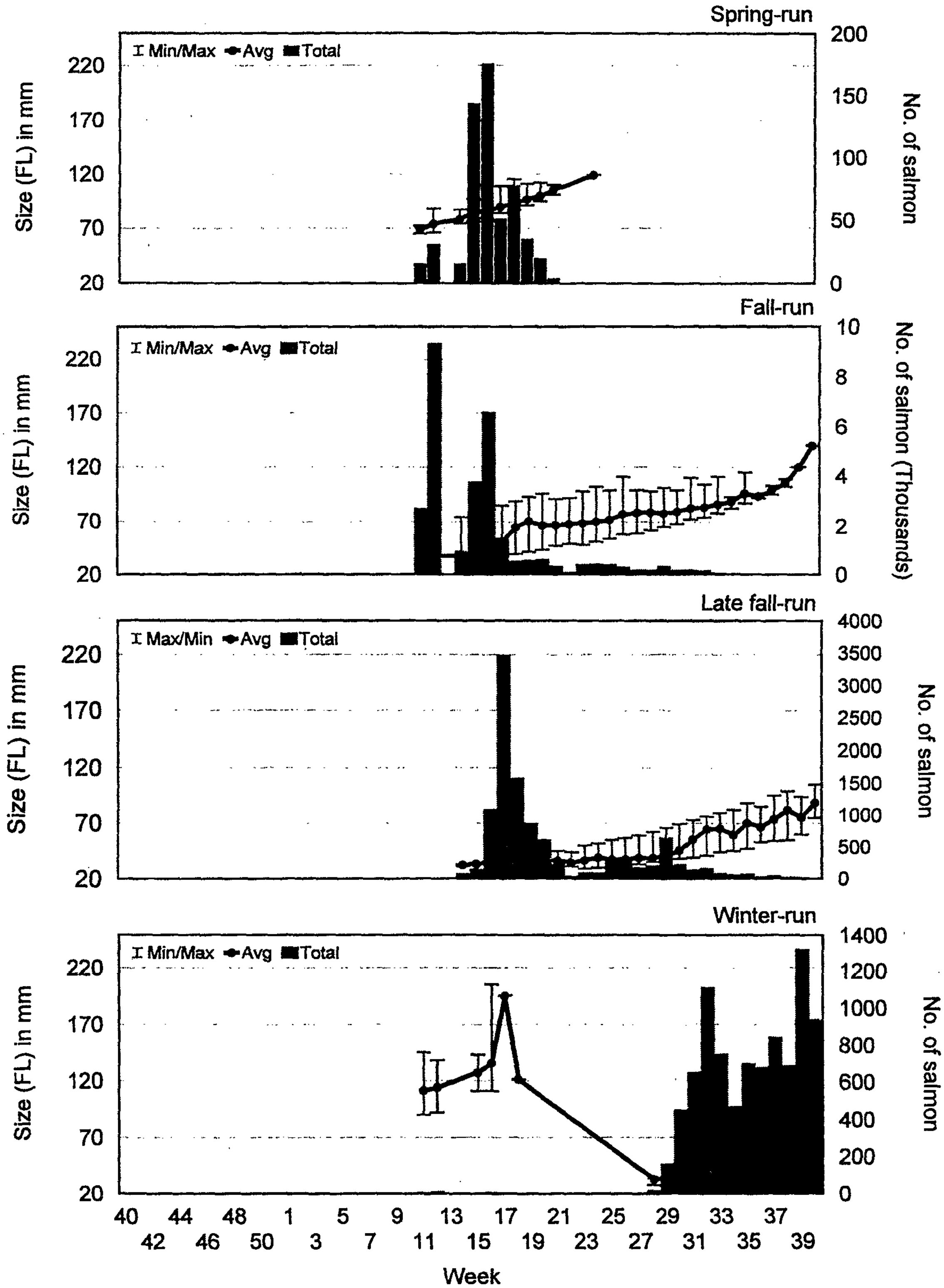


Figure 33. Weekly catch and size statistics for the four races of chinook salmon collected by rotary screw trap in the upper Sacramento River, 01 October, 1997 - 30 September, 1998.

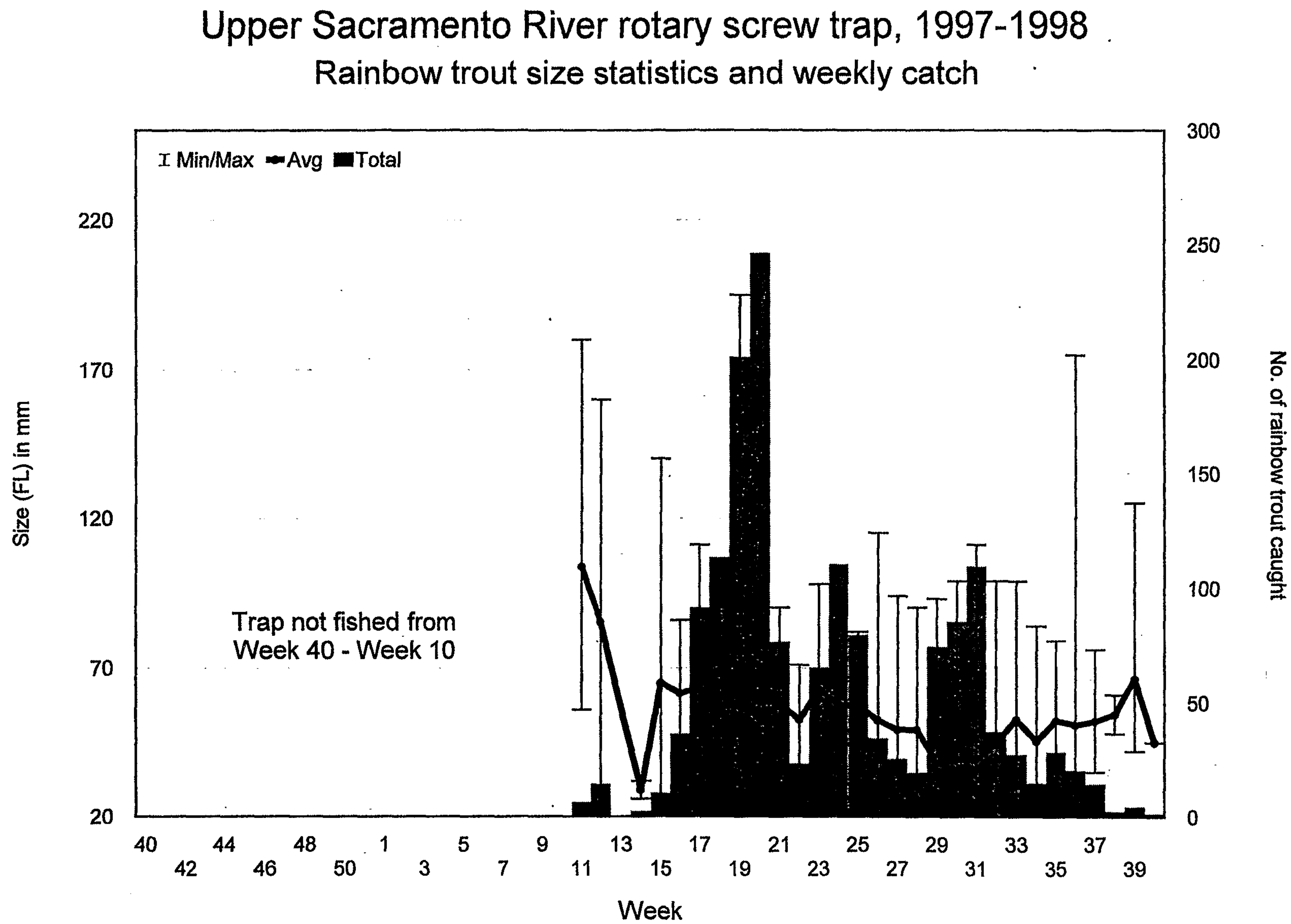


Figure 34. Rainbow trout mean fork length (minimum and maximum) and total caught by rotary screw trap in the upper Sacramento River, October 1997 - September 1998.

D-025548

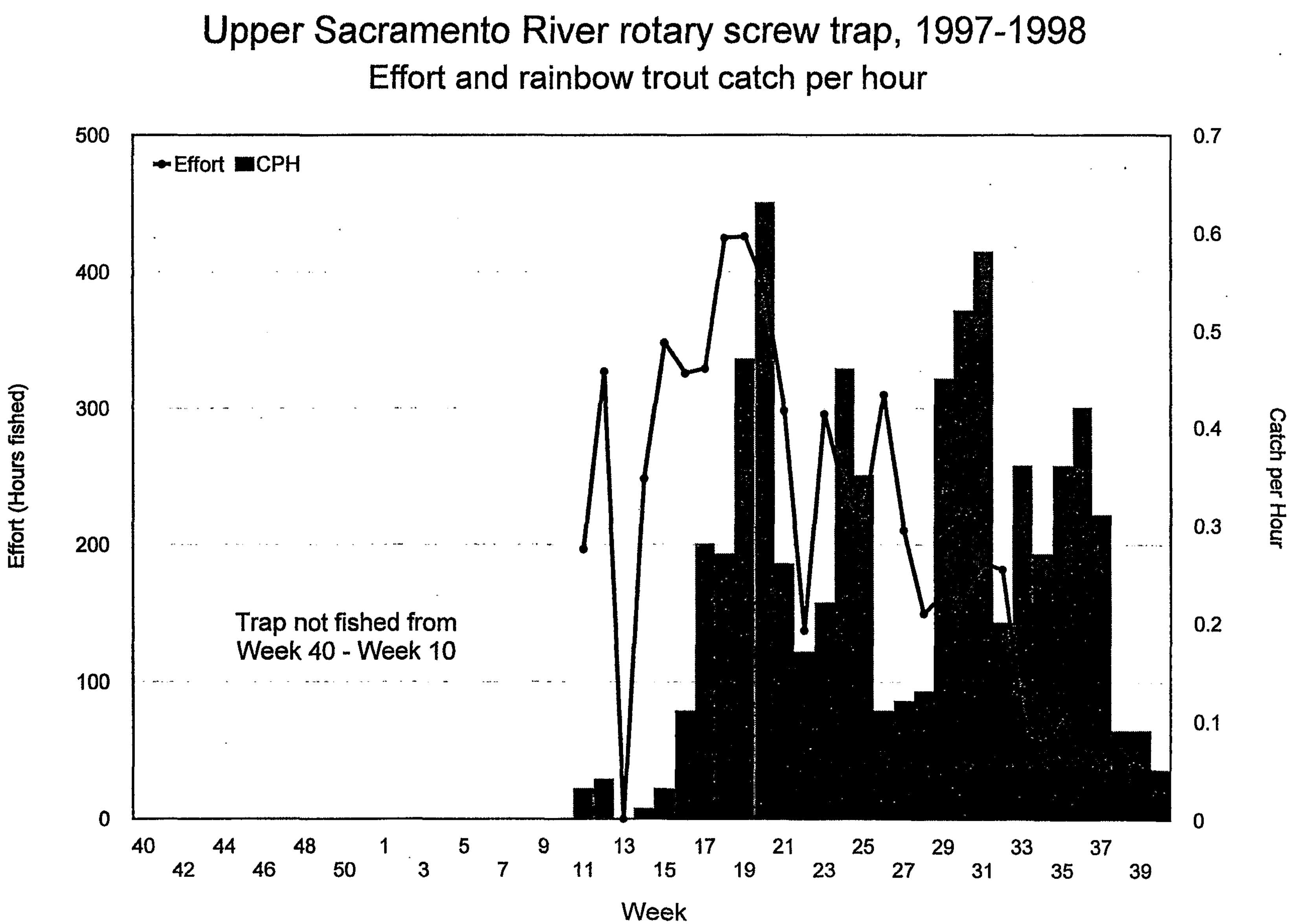


Figure 35. Weekly catch per hour of rainbow trout and hours fished by rotary screw trap in the upper Sacramento River, 01 October, 1997 - September 30, 1998.

D-025549

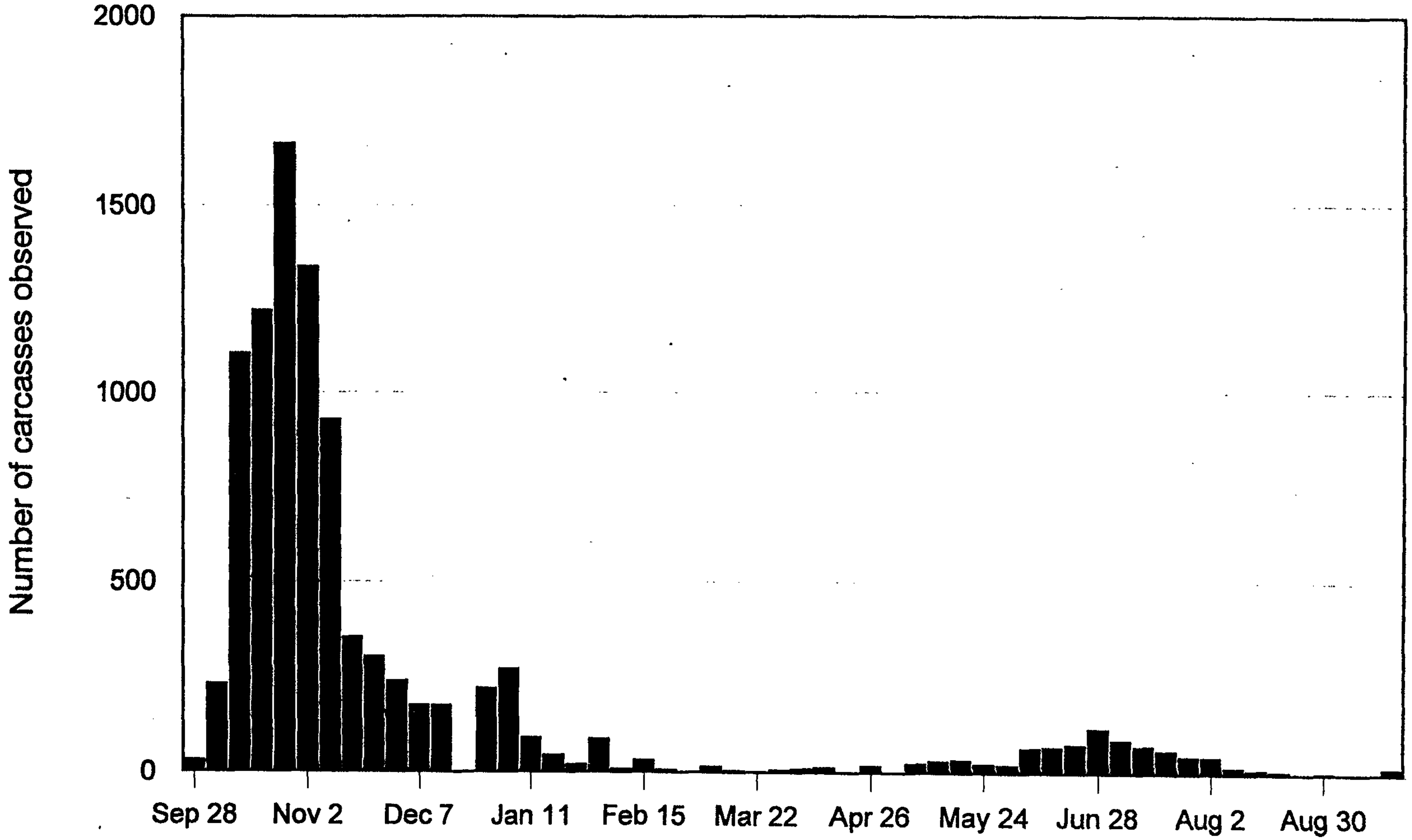


Figure 36. Weekly summary of chinook salmon carcasses observed during upper Sacramento River escapement surveys, September 28, 1997 through Spetember 30, 1998.

D-025550

APPENDIX I

Upper Sacramento River Habitat Type Distribution List

Sacramento River, Habitat Types, Battle Creek (RM 271) to Keswick Dam (RM 302)

Habitat ID #	Habitat Type	Landmark	River Mile
1	BC run		271
2	BC run		
3	BC riffle		
4	BC riffle		
5	BC pool	Barge Hole/Battle Creek	
6	BC riffle		
7	BC glide		
8	FW glide		272
9	BC run		273
10	BC riffle	Cottonwood Creek	
11	FW glide	Redding Island	274
12	FW run		275
13	FW riffle		276
14	FW glide	Balls Ferry Bridge Crossing	
15	FW pool		277
16	FW run	Ash Creek	
17	FW riffle		
18	FW glide	Bear Creek	
19	FW run		278
20	BC run		
21	BC riffle		
22	BC run		
23	BC riffle		
24	FW glide		
25	FW run		
26	FW riffle	Power Line riffle	279
27	FW glide		
28	BC pool	Haas Hole	
29	BC run	Cow Creek	280
30	BC riffle		

Habitat ID #	Habitat Type	Landmark	River Mile
31	BC run		
32	BC riffle		
33	FW glide		
34	BC run	Deschutes Rd Xing/Stillwater Creek	281
35	OC area		
36	BC riffle	Hawes riffle	
37	OC area		
38	BC glide		282
39	FW glide		
40	FW run		
41	BC riffle		
42	FW pool		
43	FW glide		
44	FW pool		283
45	FW glide	North Street Bridge /Churn Creek	284
46	FW run	Hwy 5 Crossing	285
47	FW pool		
48	FW glide		
49	FW run		
50	FW riffle	Lower Plywood riffle	
51	FW glide		286
52	FW run		
53	BC riffle	Upper Plywood Riffle	
54	FW run		
55	FW riffle		
56	FW glide		287
57	FW glide		
58	FW run		
59	BC riffle		
60	BC riffle		
61	SC riffle		
62	BC run		

Habitat ID #	Habitat Type	Landmark	River Mile
63	BC run		
64	BC riffle	Joe Deering riffle	
65	OC area		
66	BC riffle		
67	FW glide		
68	BC riffle		
69	BC riffle		
70	BC glide		
71	OC area		289
72	OC area		
73	BC run		
74	OC area		
75	BC riffle		
76	SC riffle		
77	SC pool		
78	SC riffle		
79	OC area		
80	SC pool	Olney Creek	
81	BC glide		290
82	SC run		
83	SC riffle		
84	SC riffle		
85	BC run		
86	BC riffle		
87	BC glide		
88	BC riffle		
89	OC area		
90	FW glide		291
91	FW run		
92	SC riffle		
93	SC run		
94	SC riffle		

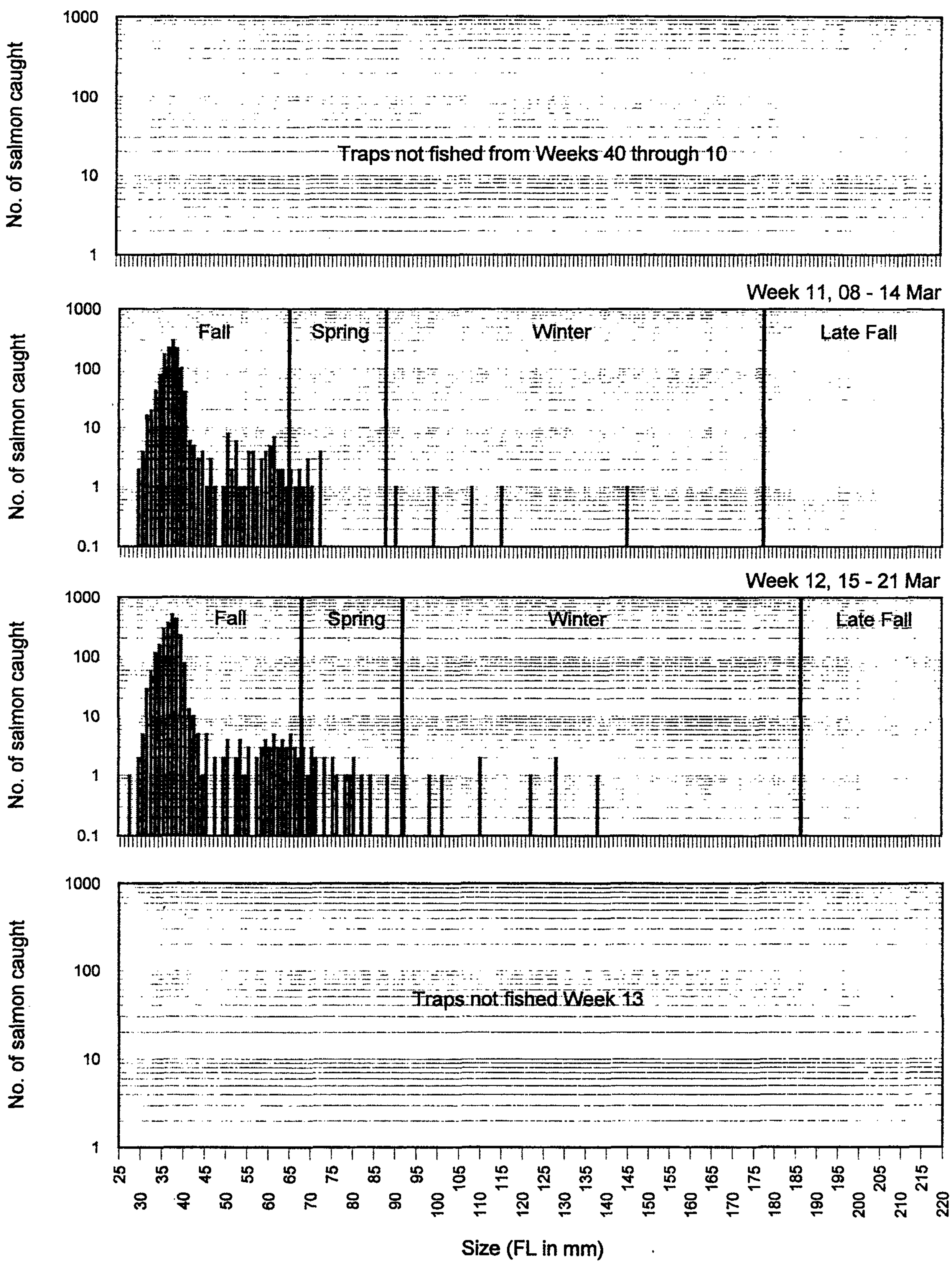
Habitat ID #	Habitat Type	Landmark	River Mile
95	OC area		
96	SC run		
97	SC riffle	Tobiasson riffle	
98	BC riffle		
99	FW glide		292
100	FW run	South Bonny View Road Crossing	
101	BC pool		
102	BC riffle		
103	BC riffle	Golf Course riffle	
104	BC run		293
105	FW run		
106	BC run		
107	OC area		
108	BC riffle	Wyndom riffle	
109	FW glide		294
110	BC glide		
111	BC run		
112	BC riffle	Cypress Avenue Bridge Crossing	295
113	BC glide		
114	OC area		
115	BC run		
116	OC area	Kutras Lake	
117	BC riffle		
118	BC pool		
119	BC riffle		
120	FW glide		
121	FW run	Kutras Island	
122	FW run		
123	BC riffle	East Island	
124	BC riffle	Turtle Bay East	
125	BC riffle	West Island	
126	OC area		

Habitat ID #	Habitat Type	Landmark	River Mile
127	OC area		
128	SC riffle		
129	BC glide	Hwy 299- 44 /Turtle, Bay West	
130	BC pool		
131	BC run		
132	BC riffle	Redding riffle	
133	FW glide	Pumping Plant	
134	FW run		
135	FW riffle		
136	FW glide		298
137	FW run		
138	FW riffle	DWR Gravel Restoration Site	
139	FW pool	ACID Dam/"Lake Redding"	
140	FW glide		
141	run	'boulder run'	300
142	pool		
143	run		301

APPENDIX II

Rotary screw trap catch weekly length distribution

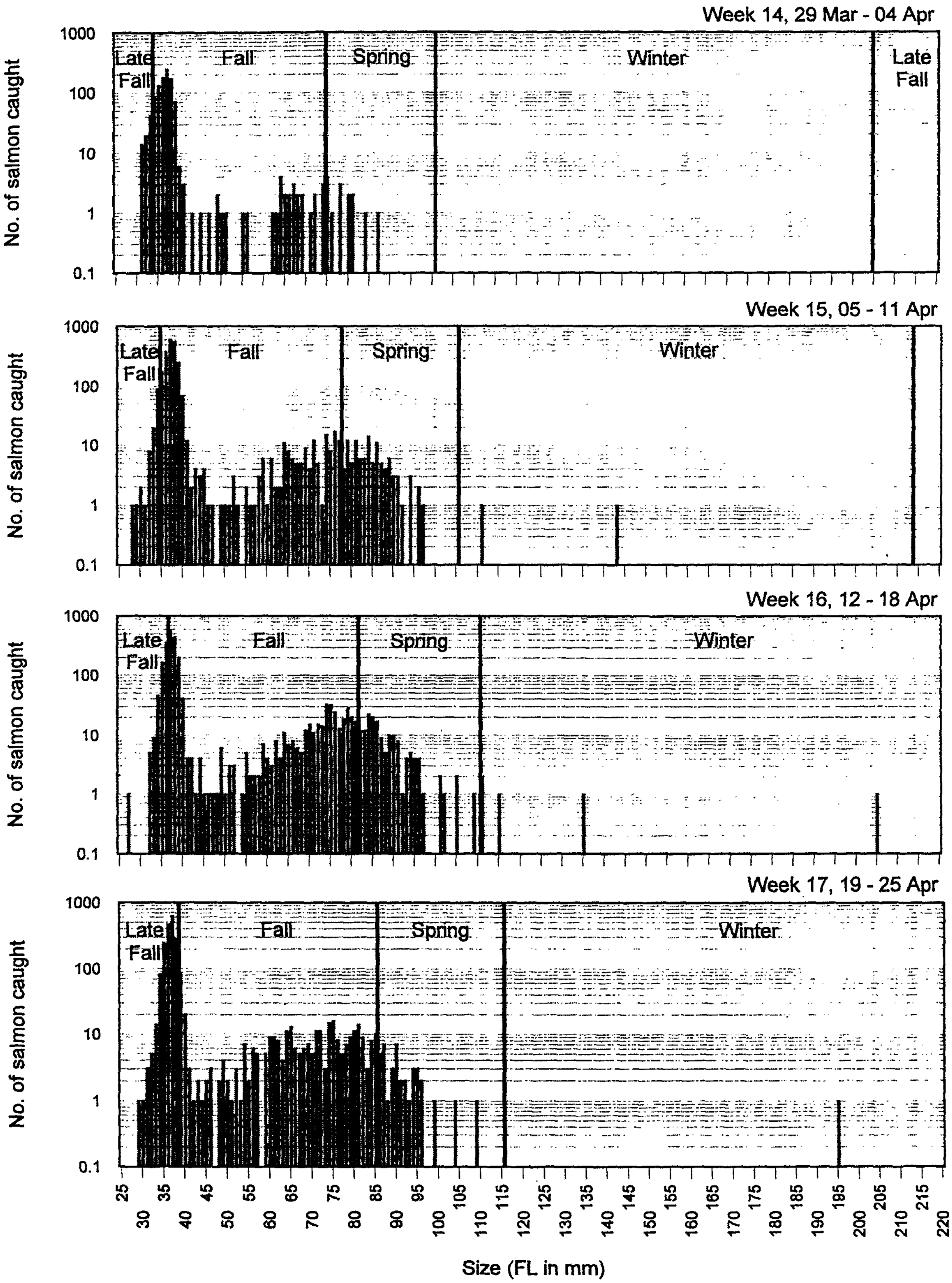
Chinook salmon Size Distribution
Upper Sacramento River rotary screw trap



II-1. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 01 October, 1997 - 28 March, 1998.

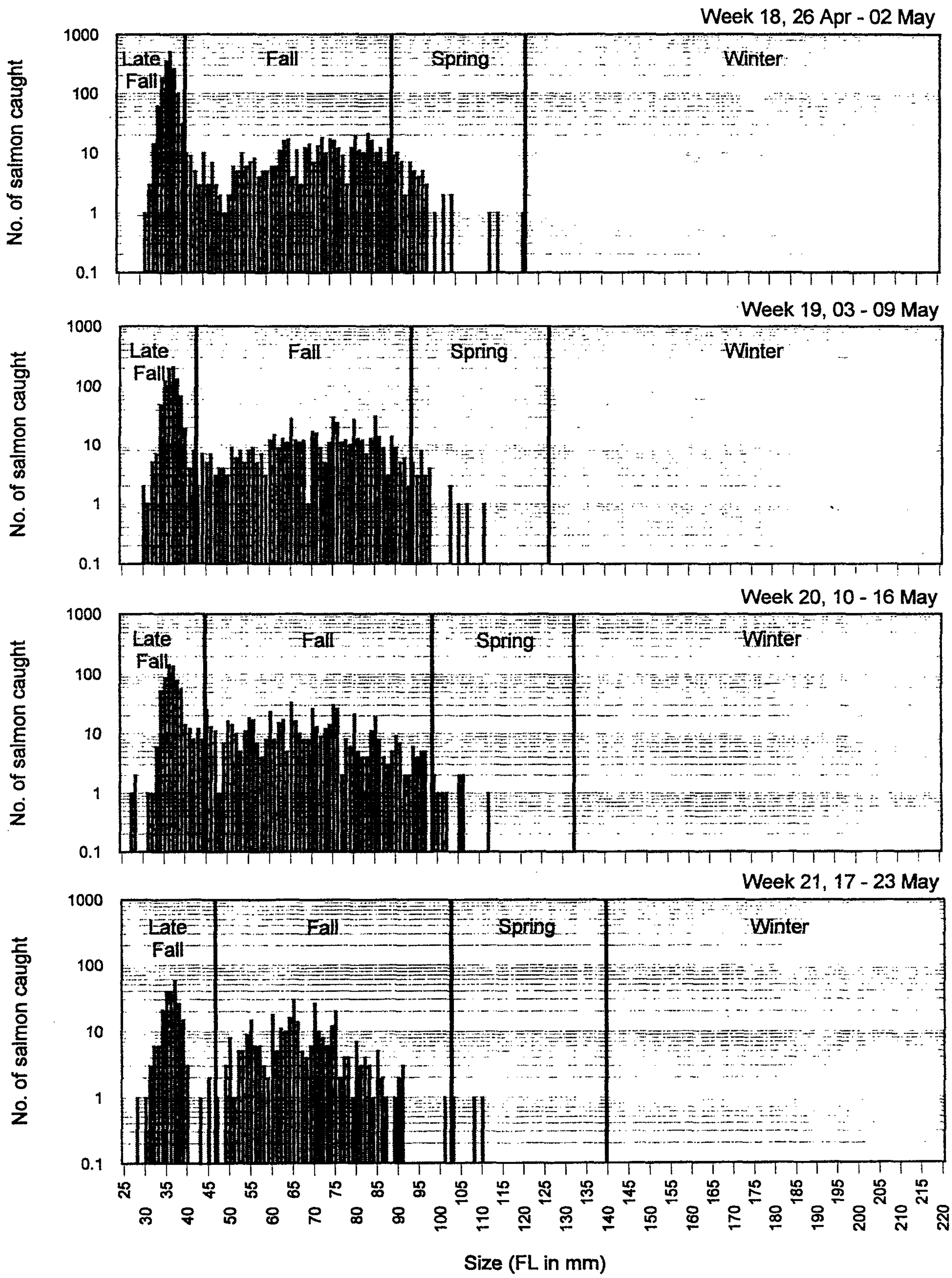
D-025558

Chinook salmon Size Distribution
Upper Sacramento River rotary screw trap

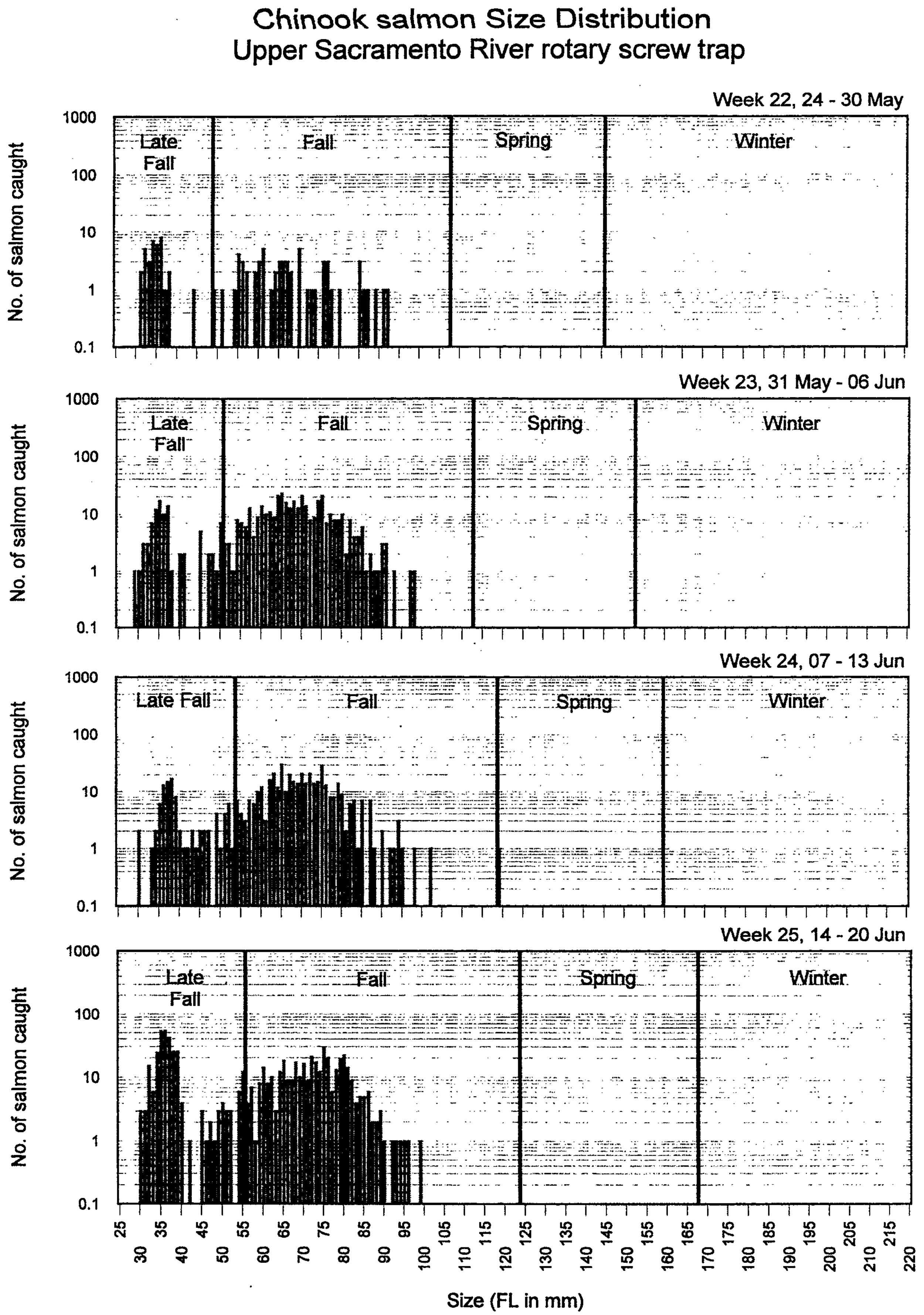


II-2. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 29 March - 25 April, 1998.

Chinook salmon Size Distribution
Upper Sacramento River rotary screw trap

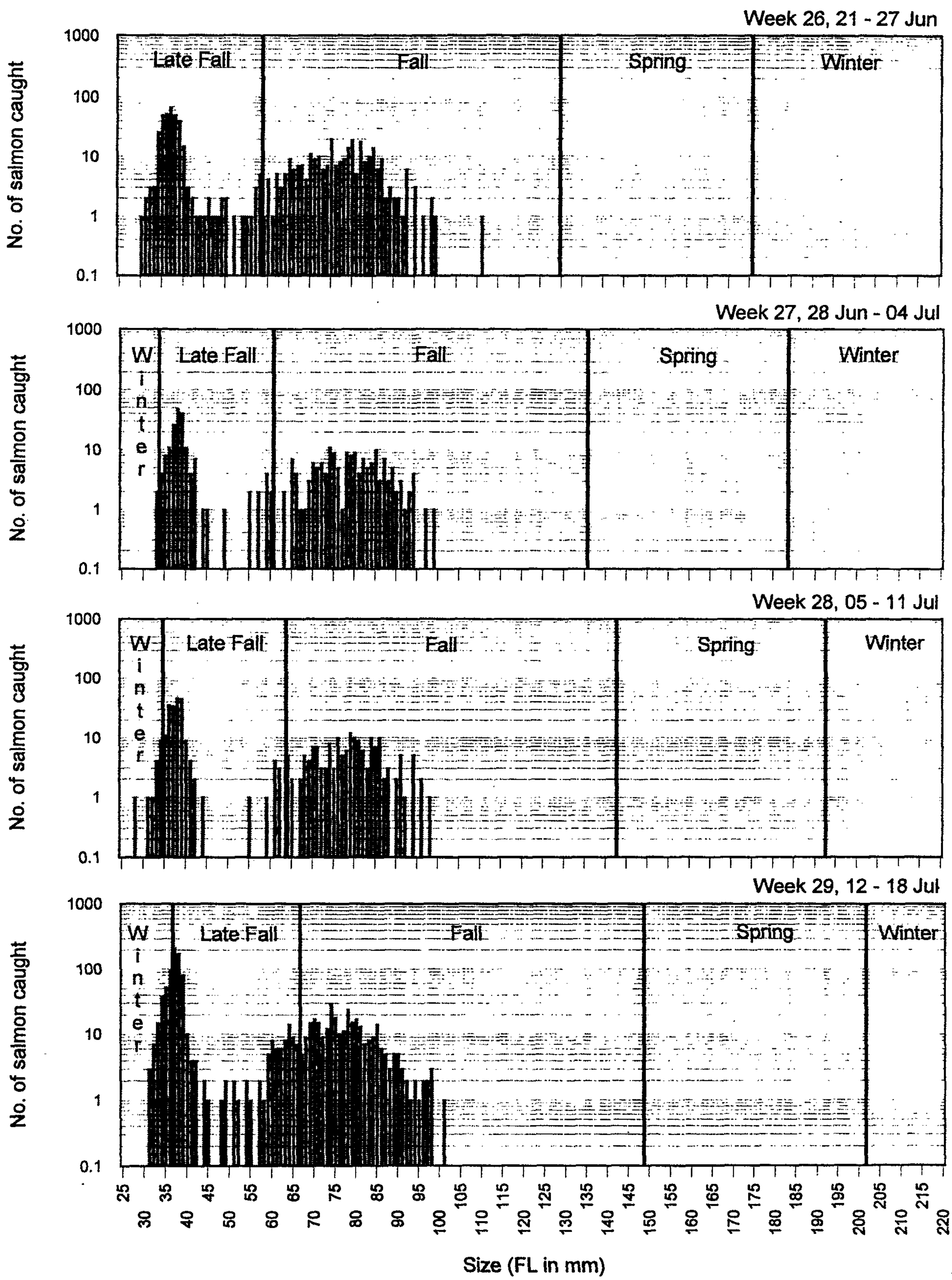


II-3. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 26 April - 23 May, 1998.



II-4. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 24 May - 20 June, 1998.

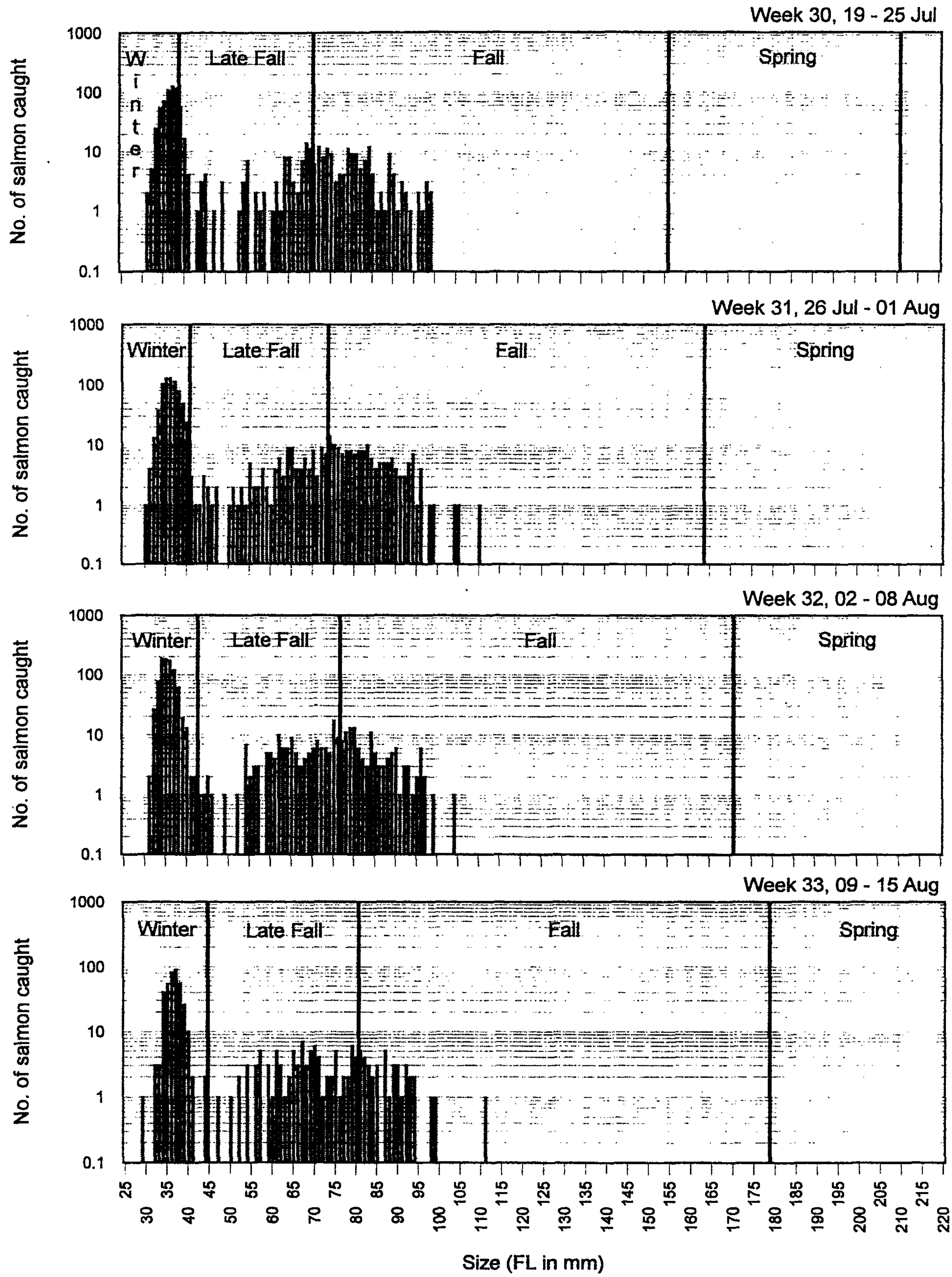
Chinook salmon Size Distribution
Upper Sacramento River rotary screw trap



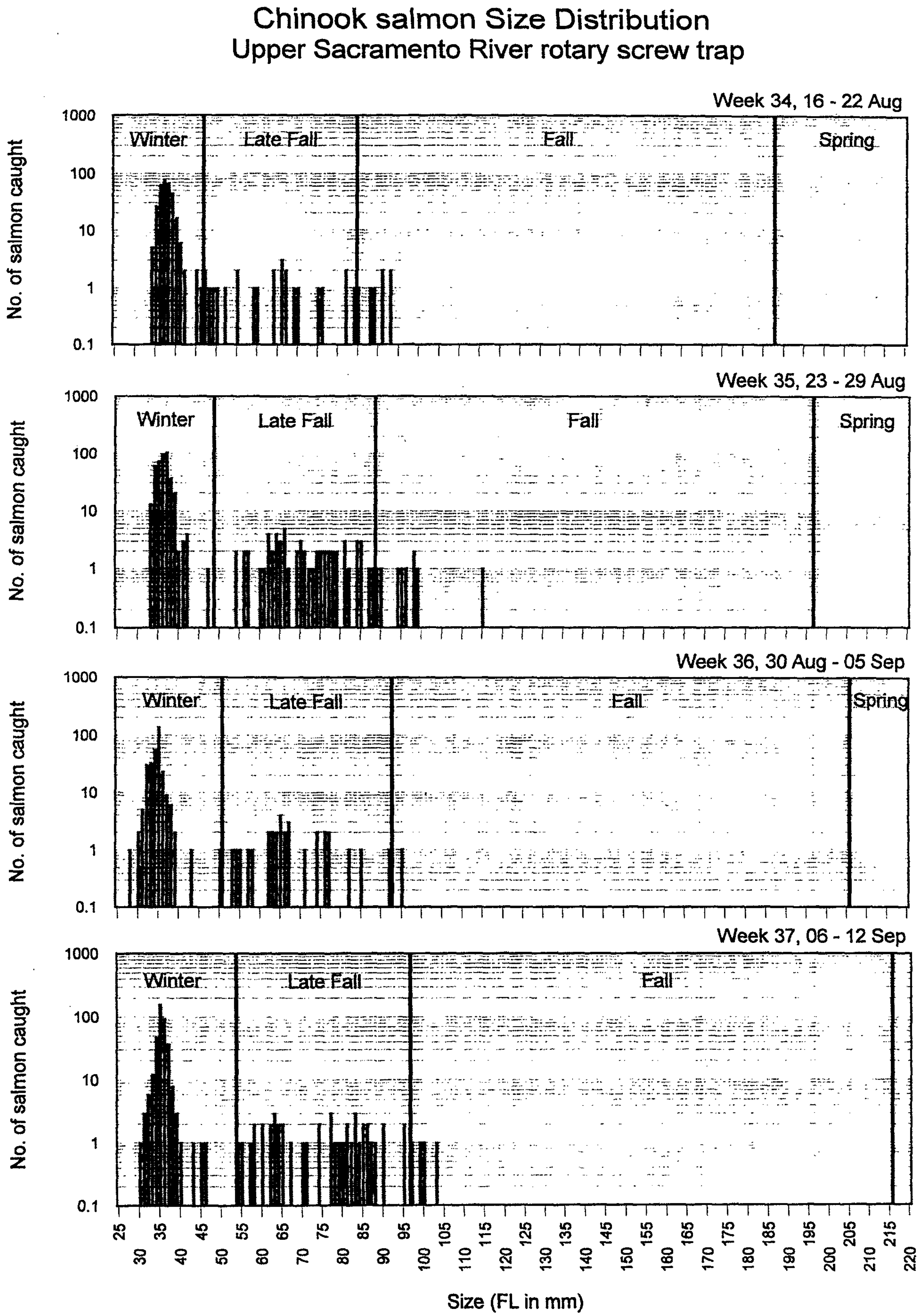
II-5. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 21 June - 18 July, 1998.

D —0 2 5 5 6 2

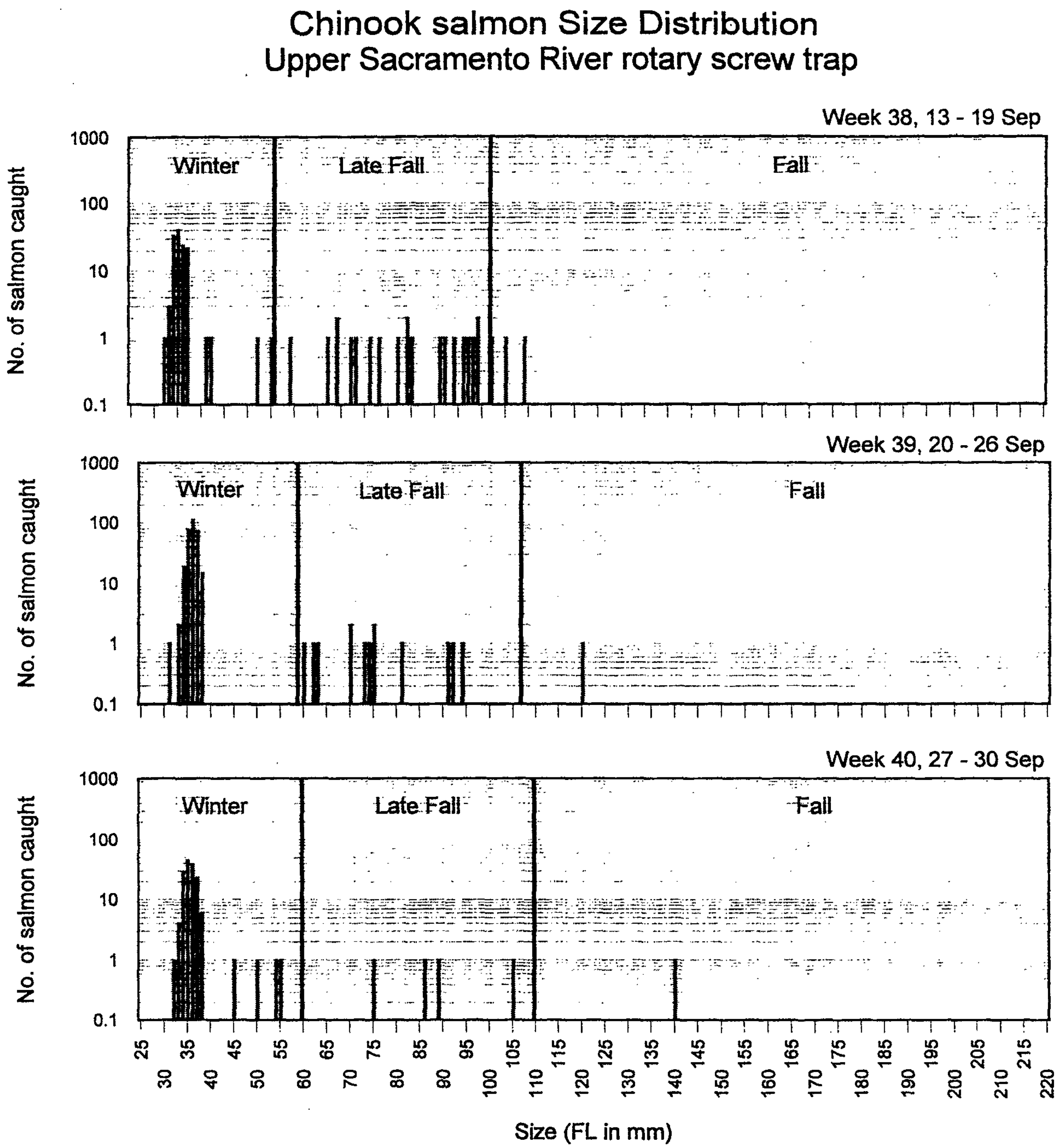
Chinook salmon Size Distribution
Upper Sacramento River rotary screw trap



II-6. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 19 July - 15 August, 1998.



II-7. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 16 August - 12 September, 1998.



II-8. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 13 - 30 September, 1998.

APPENDIX III

Fall-run chinook salmon spawner survey report

CALIFORNIA DEPARTMENT OF FISH AND GAME
Environmental Services Division
Stream Evaluation Program

Upper Sacramento River Fall-Run Chinook Salmon Escapement Survey September - December 1997[1/]

by

Bill Snider
Bob Reavis
and
Scott Hill

July 1998

1/ This work was supported by funding provided by U.S. Fish and Wildlife, Service Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of fish and Game pursuant to the Central Valley Project Improvement Act (P.L. 102-575).

SUMMARY

A fall-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey was conducted in the upper Sacramento River during fall-winter 1997 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality and temporal and spatial distribution of spawning. This was the third consecutive year a fall-run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system (Snider et. al. 1997; Snider et. al. 1998).

The survey was conducted from 29 September through 18 December 1997. It included 25.5 miles of the Sacramento River, from Cottonwood Creek to Anderson-Cottonwood Irrigation District (ACID) dam located just 3.5 miles downstream of Keswick Dam (the upstream limit to migration). Flow decreased from 6,300 cubic feet per second (cfs) during survey period 1 (29 September - 2 October 1997), to 4,900 cfs in survey period 2 (6 - 9 October 1997), and then ranged from 4,200 to 4,600 cfs for the remainder of the survey season. Mean weekly water temperature ranged from 53° F during survey periods 11 and 12 (8 - 18 December 1997) to 57° F during survey period 3 (14 - 17 October 1997).

We examined 7,754 fall-run carcasses (fresh and decayed) of which 1,219 fresh carcasses were measured, sexed, and aged; 1,448 fresh carcasses were observed. Based upon this sample, 90% of the population were adult salmon (>2-years old) and 10% were grilse (2-years old); 37% were adult males, 53% were adult females, 8% were male grilse and 2% were female grilse (45% male; 55% female). Carcasses were observed during every week of the survey. Peak carcass recovery occurred during survey periods 3 through 7 (14 October - 14 November 1997) which indicated that peak spawning likely occurred from 1 - 31 October 1997.

We examined 639 females for egg retention. Of these, 587 (92%) had completely spawned; 20 (3%) still contained a substantial number of eggs; and 32 (5%) were unspawned.

The spawner population was estimated using two different mark-recapture models, the Schaefer and Jolly-Seber models. Per the Schaefer model, 981 fresh adult carcasses were marked and 305 (31%) were subsequently recaptured yielding an escapement estimate of 26,191 total salmon (23,572 adult and 2,619 grilse). Per the Jolly-Seber model, 5,783 fresh and decayed carcasses were marked and 1,494 (26%) were subsequently recaptured yielding an estimate of 19,506 total salmon (17,555 adults and 1,951 grilse). Both estimates are considerably less than the mean annual fall-run chinook salmon escapement estimate (66,779 grilse and adult) for 1956 through 1997. Escapement estimates(Schaefer model) from the recent three annual carcass surveys have been nearly equal ranging from 26,191 to 28,890 with an mean of 27,210 and standard deviation of 1,466.

INTRODUCTION

The California Department of Fish and Game's (DFG) Stream Evaluation Program (STEP) conducted an intensive fall-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey on the upper Sacramento River during the fall of 1997 to estimate spawner abundance and distribution. This survey was carried out to fulfill the mandates of Section 3406(b)(1)(B) of the Central Valley Project Improvement Act (CVPIA), P.L. 102-575, which requires the Secretary of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers. Flow-need recommendations are to be provided to the Secretary by the U. S. Fish and Wildlife Service (FWS) after consultation with the DFG. In response to this Act, the FWS and the DFG have signed a "Cooperative Agreement" by which the FWS will fund the DFG to conduct studies to determine flow needs of salmon in the upper Sacramento River.

The primary charge of the STEP - to improve understanding of the relationships between salmon and habitat in the upper Sacramento River - requires reliable estimates of the spawner population to help distinguish habitat versus population influences on temporal and spatial spawning distribution (Snider and McEwan 1992, Snider *et al.* 1993, Snider and Vyverberg 1995). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. Spawning density, redd superimposition, habitat use, and other parameters can be affected by both changes in habitat conditions (flow dependent) and spawner population size. A reliable population estimate developed concurrently with redd surveys allows this distinction. An intensive spawning escapement survey also provides additional baseline information on egg retention (pre-spawning mortality), age and sex composition, and behavior relative to habitat conditions and population size.

Carcass tag-and-recapture surveys have been regularly used to estimate salmon spawner escapements in Central Valley tributary streams (e.g., American, Yuba, and Feather rivers). During these surveys, carcasses are tagged and released into running water for later recapture. This protocol was initially used in the Central Valley in 1973 to estimate the Yuba River escapement (Taylor 1974). This is the third year a carcass tag-and-recapture survey was conducted in the upper Sacramento River. Fall-run carcass surveys were also conducted in 1995 and 1996 (Snider et. al. 1997; Snider et. al. 1998).

Three models have been used by the DFG to estimate escapement using carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1994). It has been used primarily when data are insufficient to allow calculation with the other models. It is occasionally used to calculate estimates for tributary streams with typically small spawner populations (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement.

Based on Law's (1994) analysis, the Schaefer model will overestimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those typically observed in Central Valley tributaries. Similarly, based on Law's (1994) analysis, the Jolly-Seber model will slightly underestimate Central Valley spawner escapement. This model was first used to estimate escapement in the Central Valley in 1988. The Jolly-Seber model is more accurate when model assumptions are met and recovery rates are $\geq$ 10% (Boydstun 1994, Law 1994). Still, there is considerable disagreement about model use among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.)[1]. Law (1994) states that both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

HISTORICAL BACKGROUND

The history of efforts to enumerate spawner escapement in the upper Sacramento River has been described by Needham *et. al.* (1943), Fry (1961), Menchen (1970), Snider *et. al.* (1997), and Snider *et. al.* (1998); therefore, it is only briefly reviewed here.

- **1937-1942** Spawner escapement estimates were first made by counting salmon moving through the fish ladder at the ACID dam at river mile (RM) 298.5, near Redding. Annual counts were normally made from April through October or early November, when the dam was installed for irrigation.

- **1943-1945** Salmon were counted at a weir located near Balls Ferry Bridge (RM 278.5).

- **1945-1952** The FWS estimated escapement using "ground level spawning area surveys" (Fry 1961).

- **1950-1955** The DFG estimated spawner escapement by first capturing, tagging, and releasing live salmon at Fremont Weir (RM 82.5), then later recovering them as carcasses on the spawning grounds in the upper Sacramento River (Fry 1961).

- **1956-1968** The DFG estimated escapement using carcass counts and aerial redd counts. Experienced personnel estimated the proportion of salmon observed, based upon survey conditions and previous years' experience and expanded the "counts" accordingly.

---

[1] Personal communication with Frank Fisher (DFG-Inland Fisheries Division, Red Bluff) and Fred Meyer (DFG -Region 2, Sacramento (retired)).

- **1969-1985** Estimates were based on season-long counts of salmon moving through the fish ladders at Red Bluff Diversion Dam (RBDD) (RM 243). Aerial redd counts were used to determine the proportions of the run spawning above and below RBDD.

- **1986 - present** The DFG's Inland Fisheries Division (IFD) annually estimates fall-run escapement using both counts made at RBDD and aerial redd surveys. The dam's gates are now typically open between mid-September and mid-May of the following year improving fish passage but eliminating direct counts at the ladders during up to 8 months of the year. The number of fall-run spawners migrating upstream of RBDD is now based upon an expansion of the number of fish counted when the gates are lowered and fish are forced to migrate through fish ladders passing over the diversion.

When monitoring stocks over a long period, as is the case for the Central Valley salmon escapement surveys, the sampling design should assure the data be collected in a consistent manner and represent the population as a whole (Ney 1993). Lack of these attributes from the Central Valley surveys should <u>not</u> reflect on persons who made population estimates, but on logistic limitations. Annual budgets for temporary employees needed to conduct the escapement surveys were often reduced or eliminated resulting in estimates based on less data. In addition, population estimates were often based on counts made upstream of substantial areas of fall-run spawning activity, e.g., ACID dam, Balls Ferry, and RBDD (Figure 1).

OBJECTIVES

The objectives of the 1997 upper Sacramento River fall-run chinook salmon escapement survey were:

- To estimate the 1997, in-river, fall-run chinook salmon spawning population for the upper Sacramento River upstream of Cottonwood Creek.

- To evaluate egg-retention, and sex and age composition of fall-run chinook salmon spawning in the upper Sacramento River.

- To augment redd surveys to provide baseline information on spawning distribution, spawning habitat availability, instream flow requirements, and the status of chinook salmon in the upper Sacramento River.

METHODS

The 1997 spawner escapement surveys began immediately following the initial observation of spawning activity and then were conducted weekly from 29 September through 18 December 1997. The 25.5-mile-long stream segment from ACID dam (RM 298.5) downstream to the mouth of Cottonwood Creek (RM 273.0; Figure 1) was divided into four reaches (Table 1). Each reach was surveyed one day per week.

Table 1. Location of survey reaches during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1997.

Reach	Location	River mile (length)
1	ACID Dam to Cypress St. Bridge	298.5 - 295.0 (3.5)
2	Cypress St. Bridge to Bonnyview Bridge	295.0 - 292.0 (3.0)
3	Bonnyview Bridge to North St. Bridge	292.0 - 284.0 (8.0)
4	North St. Bridge to Cottonwood Bridge	284.0 - 273.0 (11.0)

Surveys were primarily conducted using two boats with two observers per boat. The observers attempted to locate and collect carcasses as each boat traversed the river between the center of the channel and one of the channel margins. Collected carcasses were checked for completeness (i.e., with the head intact) and previous tags. Complete, untagged carcasses were usually tagged by attaching a colored ribbon (to indicate week tagged) to the jaw using a hog ring. Carcasses that were not tagged were chopped in half. Chopped carcasses included: i) those previously tagged, ii) those on shore in a "leathery condition"; iii) those in Reach 4 (the most downstream reach) that would likely wash out of the survey area and never be recovered; and, iv) carcasses in excess of the number that crews could tag during a day. Tagged carcasses were released into running water for recapture. Data collected to estimate population size included number tagged, number chopped, and number recovered.

All carcasses were also examined for eye clarity and gill color to determine freshness. Carcasses were considered fresh if either eye was clear or gills were pink. Data collected from a subsample of the fresh carcasses included gender, fork length (FL) in centimeters, reach of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining; as partially spent if a substantial amount of the eggs remained; and unspent if the ovaries appeared nearly full of eggs.

To be consistent with the standard protocol that has been used on most Central Valley streams, escapement estimates were determined using fresh carcass data to calculate a Schaefer model estimate, and both fresh and decayed carcass data to calculate a Jolly-Seber model estimate.

The formulas used to derive the escapement estimates (E) are as follows:

Schaefer model: $E = N_{ij} = R_{ij}(T_iC_j/R_iR_j) - T_i$

where:

N_{ij} = Population size in tagging period *i* recovery period *j*,
R_{ij} = number of carcasses tagged in the *i*th tagging period and recaptured in the *j*th recovery period,
T_i = number of carcasses tagged in the *i*th tagging period,
C_j = number of carcasses recovered and examined in the *j*th recovery period,
R_i = total recaptures of carcasses tagged in the *i*th tagging period, and
R_j = total recaptures of tagged carcasses in the *j*th recovery period.

This model differs from the original in that the number of tags applied after the first week is subtracted from the population estimate to account for sampling with replacement. Schaefer's original model was based on sampling without replacement while in salmon survey conditions, sampling occurs with replacement.

Jolly-Seber model: $E = N_1 + D_1 + D_2 ... + D_j$

where:

N_1 = Number of carcasses in the population in period 1, the first period of spawning and dying, and
D_i = number of carcasses that joined the population between periods *i* and *i*+1, with j as the last survey period.

Calculation of the basic quantities used in the Jolly-Seber model has been described in detail by Boydstun (1994).

Flow measurements for each day surveyed were obtained from the Keswick gauge operated by the U.S. Geological Survey. Water temperature (grab sample) and water visibility (Secchi depth) were measured daily by the survey crew.

D-025573

RESULTS AND DISCUSSION

A total of 7,754 carcasses was observed (Table 2). Flow averaged 6,300 cubic feet per second (cfs) during the first survey period, 4,900 cfs during the second survey period, and ranged from 4,200 to 4,600 cfs during survey periods 4 through 12 (Table 2, Figure 2). Mean temperature ranged from 53° F during survey periods 11 and 12 to 57° F during survey period 3 (Table 2, Figure 2). Water clarity (Secchi depth) ranged from 5 ft (Survey period 8) to 12 ft (survey periods 3 and 4) (Table 2, Figure 2)

Temporal Distribution

The number of carcasses observed increased steadily from survey period 1 through 5 (29 September - 30 October), and then declined thereafter (Table 2 and Figure 3).

Spatial Distribution

The distribution of the total carcasses observed per reach was 28% in Reach 1, 34% in Reach 2, 24% in Reach 3, and 14% in Reach 4 (Table 3 and Figure 4).

Size Distribution

A total of 1,219 carcasses was measured (Table 4). Mean adult size was 81.6 cm FL. Size ranged from 42 to 112 cm FL. Male salmon (n = 548) averaged 84.4 cm FL (range: 42 - 112 cm FL) (Figure 5). Female salmon (n = 671) averaged 79.2 cm FL (range: 58 - 98 cm FL) (Figure 6). The weekly mean size for males ranged from 64.4 to 87.1 cm FL (Figure 7). Weekly mean size for females ranged from 77.4 to 84.6 cm FL (Table 4 and Figure 8).

Length-frequency distributions were used to define a general size criterion distinguishing grilse (2-year-old salmon) and adults (>2-year-old salmon) for each sex (Figures 5 and 6). Male grilse (n=94) were defined as salmon ≤ 72 cm FL, and female grilse (n=22) were defined as salmon ≤ 66 cm FL (Table 5). Male grilse averaged 61.7 cm FL (range: 42 - 72 cm FL, SD=8.0); male adults (n=454) averaged 89.0 cm FL (range: 73 - 112 cm FL, SD=8.2). Female grilse averaged 63.8 cm FL (range: 58 - 66 cm FL, SD=2.1); female adults (n=649) averaged 79.7 FL (range: 67 - 98 cm FL, SD=6.8).

Grilse comprised 116 (10%) of the 1,219 measured carcasses (Table 6). The greatest number of grilse (22) was observed in the fifth survey period (27 - 30 October) (Figure 9). Adults comprised 1,103 (90%) of the measured carcasses. The greatest number of adults (221) was observed during Survey period 3 (14 - 17 October).

Table 2. General survey information for the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1997.

Survey period	Dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (°F)[2/]	Carcass count[3/]	
					Fresh	Decayed
1	Sep 29 - Oct 2	6,300	10	54	14	16
2	Oct 6 - 9	4,900	9	54	108	123
3	Oct 14 - 17	4,500	12	57	312	791
4	Oct 20 - 23	4,300	12	56	280	938
5	Oct 27 - 30	4,400	11	57	247	1,415
6	Nov 3 - 6	4,600	10	56	139	1,197
7	Nov 10 - 14	4,600	9	56	103	824
8	Nov 17 - 20	4,600	5	54	48	305
9	Nov 24 - 26	4,200	7	55	57	246
10	Dec 1 - 4	4,200	9	54	49	190
11	Dec 8 - 11	4,200	9	53	38	138
12	Dec 15 - 18	4,200	8	53	53	123
				Totals	1,448	6,306

1/ Weekly average discharge during days sampled as measured at Keswick Dam by U.S. Bureau of Reclamation.
2/ Weekly average of daily measurements taken by survey crews.
3/ Includes both adults and grilse.

D-025575

Table 3. Distribution of carcass (adults and grilse) observed during the upper Sacramento River fall-run chinook salmon escapement survey, September-December 1997.

Survey period	Reach 1		Reach 2		Reach 3		Reach 4	
	M[1/]	C[2/]	M	C	M	C	M	C
1	11	0	11	0	7	0	1	0
2	35	12	104	17	42	15	6	0
3	248	11	424	20	244	18	126	12
4	234	11	504	20	239	29	164	17
5	332	27	564	47	345	73	256	18
6	344	64	262	66	288	46	218	48
7	224	84	156	54	160	87	130	32
8	99	82	68	53	26	3	16	6
9	92	35	53	27	49	37	8	2
10	75	28	26	24	44	19	13	10
11	0	84	0	44	0	36	0	12
12	0	83	0	48	0	34	0	11
Total	1,694	521	2,172	420	1,444	397	938	168

1/ Number of carcasses tagged.
2/ Number of untagged carcasses chopped.

D-025576

Table 4. Size and sex statistics for fresh fall-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, September - December 1997.

Survey period	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm)		Number measured	Length (FL in cm)		Number measured	Length (FL in cm)	
		Mean	Range		Mean	Range		Mean	Range
1	14	69.9	42-105	9	64.4	42-105	5	79. 6	71-88
2	108	82.1	49-105	67	84.0	49-105	41	78.9	65-98
3	238	82.4	54-111	111	85.7	54-111	127	79.5	64-98
4	205	82.4	45-112	86	87.1	45-112	119	79.0	64-94
5	195	80.0	51-108	83	83.5	51-108	112	77.4	59-94
6	135	80.9	51-100	46	84.3	51-100	89	79.1	63-95
7	89	80.9	52-103	29	84.8	52-103	60	79.0	62-95
8	48	80.3	58-101	19	84.6	60-101	29	77.4	58-98
9	52	82.1	53-105	26	83.5	53-105	26	80.7	66-95
10	48	82.0	44-106	22	83.0	44-106	26	81.0	67-92
11	38	84.4	44-109	23	84.2	44-109	15	84.6	71-94
12	49	82.5	55-107	27	82.0	55-107	22	83.2	62-93
Total (mean)	1,219	(81.6)	42-112	548	(84.4)	42-112	671	(79.2)	58-98

D-025577

Table 5. Summary of adult and grilse sizes and numbers by sex for carcasses measured during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1997.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	22	649	94	454
Mean FL (cm)	63.8	79.7	61.7	89.0
Range FL (cm)	58-66	67-98	42-72	73-112
SD	2.1	6.8	8.0	8.2

Table 6. Age composition (grilse and adult) of carcasses measured during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1997.

	Adults		Grilse	
Survey period	Number	Percent	Number	Percent
1	8	57	6	43
2	96	89	12	11
3	221	93	17	7
4	195	95	10	5
5	173	89	22	11
6	124	92	11	8
7	84	94	5	6
8	44	92	4	8
9	44	85	8	15
10	41	85	7	15
11	33	87	5	13
12	40	82	9	18
Total(mean)	1,103	(90)	116	(10)

Sex Composition

Males comprised 41% (n = 454) of the fresh adult carcasses examined, while females comprised 59% (n=649)(Table 7). Of the fresh grilse observed, males comprised 81% (n=94) and females comprised 19% (n=22). Females comprised 55% (n=671) of the all fresh carcasses examined and males comprised 45% (n=548).

The female to male ratio for adult spawners was nearly 1.4:1 (649:454) (Table 7 and Figure 10). Females dominated the adult population throughout the survey period; the grilse population was mostly males (Figure 11).

Spawning Success

There were 639 females examined for egg retention (Table 8). Of these, 587 (92%) had completely spawned, 20 (3%) had only partially spawned, and 32 (5%) had not spawned. At least 73% of the females checked per week had completely spawned.

Population Estimates

Fresh carcass data were used to calculate the Schaefer estimate. A total of 981 fresh adult carcasses was tagged and 305 (31%) were subsequently recaptured. Both fresh and decayed carcass data were used to calculate the Jolly-Seber estimate. A total of 5,783 fresh and decayed adult carcasses was tagged, and 1,494 (26%) were subsequently recaptured.

An estimate of 23,572 adult spawners was calculated using the Schaefer model (Tables 9 and 10). Since adults made up 90% of the total escapement based on carcasses measured (Table 6), a total escapement estimate of 26,191 spawners (adults and grilse) was calculated by dividing the adult estimate by 0.9. An adult escapement estimate of 17,555 was calculated using the Jolly-Seber model (Table 11). This estimate was also expanded by dividing by 0.9 resulting in a total escapement estimate of 19,506 spawners.

The 1997 population estimates for salmon spawning in the upper Sacramento River from ACID Dam to Cottonwood Creek are as follows:

	Schaefer model	Jolly-Seber model
Total estimate	26,191	19,506
Adult estimate	23,572	17,555
Grilse estimate	2,619	1,951

The 1997 escapement of 26,191 is considerably less than the 1956 -1997 average of 66,779 for the section of stream from Keswick Dam to RBDD (Table 12 and Figure 12). Since most fall-run chinook salmon spawn between Cottonwood Creek and ACID dam, with very little spawning taking place upstream of ACID dam, the inclusion of the uppermost 3.5 miles of river (ACID dam to Keswick Dam) would have added little to the survey.

Table 7. Sex composition of fall-run chinook salmon grilse and adults carcasses measured during the upper Sacramento River escapement survey, September - December 1997.

Survey period	Adults				Grilse*			
	Male		Female		Male		Female	
	Number	%	Number	%	Number	%	Number	%
1	3	38	5	62	6	100	0	0
2	57	59	39	41	10	83	2	17
3	99	45	122	55	12	71	5	29
4	78	40	117	60	8	80	2	20
5	65	38	108	62	18	82	4	18
6	38	31	86	69	8	73	3	17
7	26	31	58	69	3	60	2	40
8	17	39	27	61	2	50	2	50
9	19	43	25	57	7	88	1	12
10	15	37	26	63	7	100	0	0
11	18	55	15	45	5	100	0	0
12	19	48	21	52	8	89	1	11
Total (mean)	454	(41)	649	(59)	94	(81)	22	(19)

* Based on length-frequency distributions, male grilse are defined as ≤ 72 cm FL and females grilse as ≤ 66 cm FL.

Table 8. Spawning completion (egg retention) summary for female fall-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, September - December 1997.

Survey period	No. females measured	No. females checked for egg retention	Number spawned (%)	Number partially spawned (%)	Number unspawned (%)
1	5	5	5(100)	0(0)	0(0)
2	41	41	37(90)	2(5)	2(5)
3	127	124	117(94)	2(2)	5(4)
4	119	113	100(89)	7(6)	6(5)
5	112	110	99(90)	6(5)	5(5)
6	89	86	80(93)	3(3)	3(3)
7	60	55	53(96)	0(0)	2(4)
8	29	27	26(96)	0(0)	1(4)
9	26	25	24(96)	0(0)	1(4)
10	26	20	19(95)	0(0)	1(5)
11	15	11	8(73)	0(0)	3(27)
12	22	22	19(86)	0(0)	3(14)
Total (mean)	671	639	587(92)	20(3)	32(5)

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Table 9. Summary of tagging and recapture of fresh adult chinook salmon carcasses by survey period during the upper Sacramento River escapement survey, September - December 1997

Schaefer model capture-recapture data matrix

Period of recovery $_{(j)}$	Period of tagging $_{(i)}$ 1	2	3	4	5	6	7	8	9	10	Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$	Ratio $C_{(j)}/R_{(j)}$
2	1										1	227*	227.00
3	1	16									17	1,071	63.00
4		5	65								70	1,212	17.31
5		1	17	46							64	1,623	25.36
6			6	15	56						77	1,317	17.10
7				4	12	18					34	854	25.12
8					1	4	13				18	327	18.17
9						1	5	3			9	273	30.33
10								2	3		5	208	41.60
11									2	7	9	165	18.33
12										1	1	157	157.00
$R_{(i)}$	2	22	88	65	69	23	18	5	5	8	<- Tagged fish recovered		
$T_{(i)}$	8	65	252	232	185	90	64	28	29	28	<- Total fish tagged		
$T_{(i)}/R_{(i)}$	4.00	2.95	2.86	3.57	2.68	3.91	3.56	5.60	5.80	3.50	<- Ratio		

* Included carcasses observed during Survey period 1.

D—025582

Table 10. Upper Sacramento River adult fall-run chinook salmon population estimate using the Schaefer model based on tagging fresh carcasses with all captured untagged carcasses removed, September - December 1997.

Population estimate

Period of recovery$_{(i)}$	Period of tagging $_{(j)}$										Totals
	1	2	3	4	5	6	7	8	9	10	
2	908										908
3	252	2,978									3,230
4		256	3,223								3,479
5		75	1,235	4,164							5,473
6			294	916	2,568						3,778
7				359	808	1,769					2,936
8					49	284	840				1,173
9						119	539	510			1,168
10								466	724		1,190
11									213	449	662
12										550	550
Subtotals	1,160	3,309	4,751	5,438	3,425	2,172	1,379	976	937	999	24,545
Tags		-65	-252	-232	-185	-90	-64	-28	-29	-28	-973
								Population estimate -			23,572

D-025583

Table 11. Summary of tagging and recapture of fresh and decayed adult chinook salmon carcasses by survey period during the upper Sacramento River escapement survey, September - December 1997.

Jolly-Seber capture-recapture data matrix

Period of recovery$_{(j)}$	Period of tagging $_{(i)}$ 1	2	3	4	5	6	7	8	9	10	Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$
2	4										4	233*
3	2	27									29	1,090
4		11	238								249	1,391
5		1	77	292							370	1,929
6			18	54	301						373	1,613
7				12	52	169					233	1,053
8				1	4	29	78				112	421
9					1	5	22	38			66	330
10							1	6	20		27	230
11									7	18	25	181
12									1	5	6	162
Tags recovered$_{(i)}$	6	39	333	359	358	203	101	44	28	23	<- Tagged fish recovered	
Carcasses Tagged$_{(i)}$	22	169	1,002	1,070	1,405	1,034	590	184	172	135	<- Total fish tagged	

* Includes carcasses examined during Survey period 1.

Table 12. Annual fall–run chinook salmon escapement estimates (adults and grilse) for upper Sacramento River from Keswick Dam to RBDD Diversion Dam, 1956 - 1994. (Data for years prior to 1995 provided by Frank Fisher, DFG, Red Bluff).

Year	Total	Year	Total
1956	84,716	1977	15,784
1957	47,300	1978	32,235
1958	99,300	1979	47,758
1959	249,600	1980	21,961
1960	210,000	1981	26,261
1961	134,700	1982	17,731
1962	115,500	1983	26,226
1963	135,200	1984	36,898
1964	140,500	1985	51,647
1965	98,900	1986	67,958
1966	107,900	1987	76,039
1967	78,100	1988	65,204
1968	95,600	1989	48,512
1969	114,600	1990	32,225
1970	65,950	1991	19,272
1971	52,247	1992	26,912
1972	33,559	1993	33,923
1973	40,424	1994	31,017
1974	45,590	1995	26,548
1975	52,248	1996	28,890
1976	43,612	1997	26,191

ACKNOWLEDGMENTS

The California Department of Fish and Game recognizes the efforts of Jon Ferguson, John Galos, Jeffrey Jahn, and Warren Nichols. Their efforts in the collection of field data are greatly appreciated. The data collection was funded by the FWS as a part of a cooperative agreement with the DFG as authorized by the CVPIA (P.L. 102-575).

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FIGURES

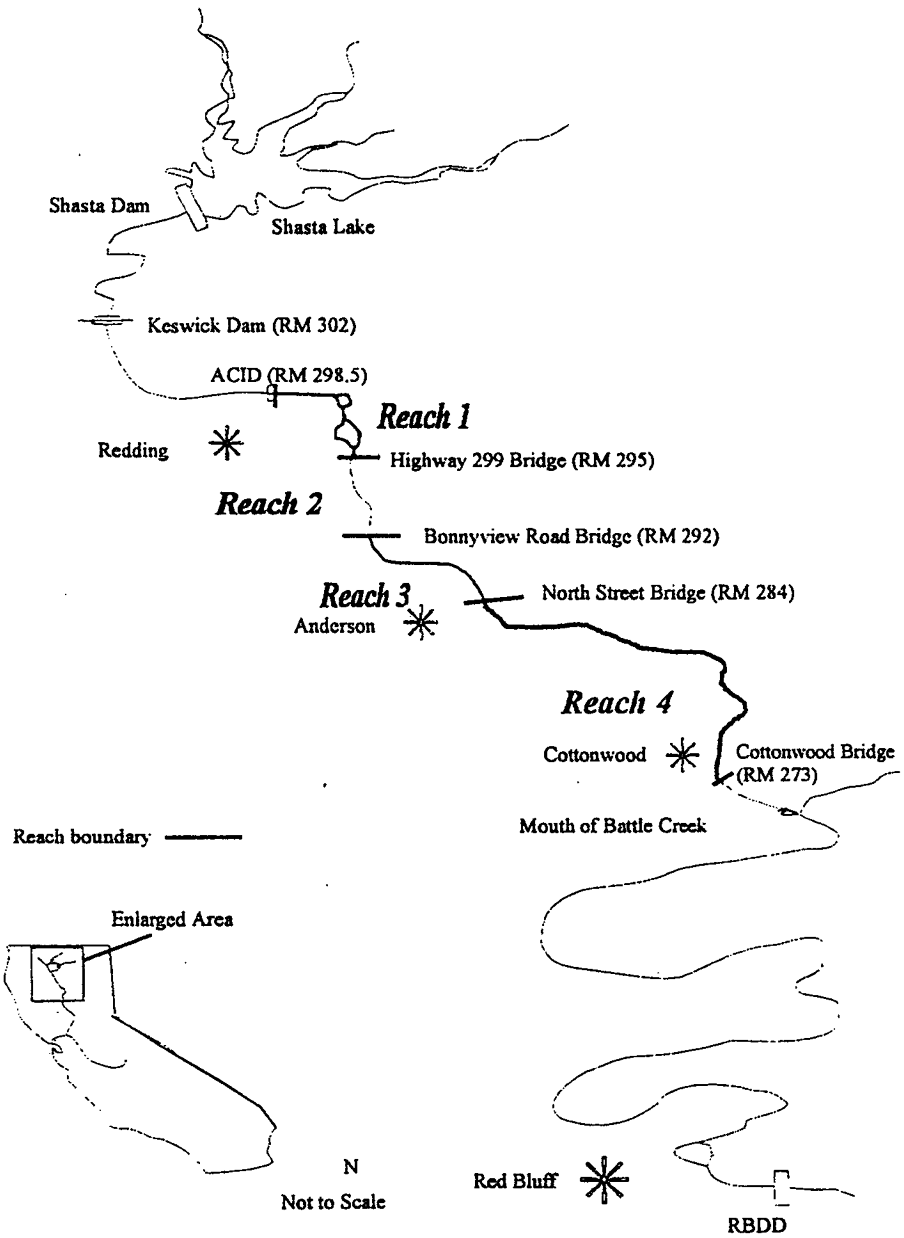

Figure 1. Location of sampling reaches in the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

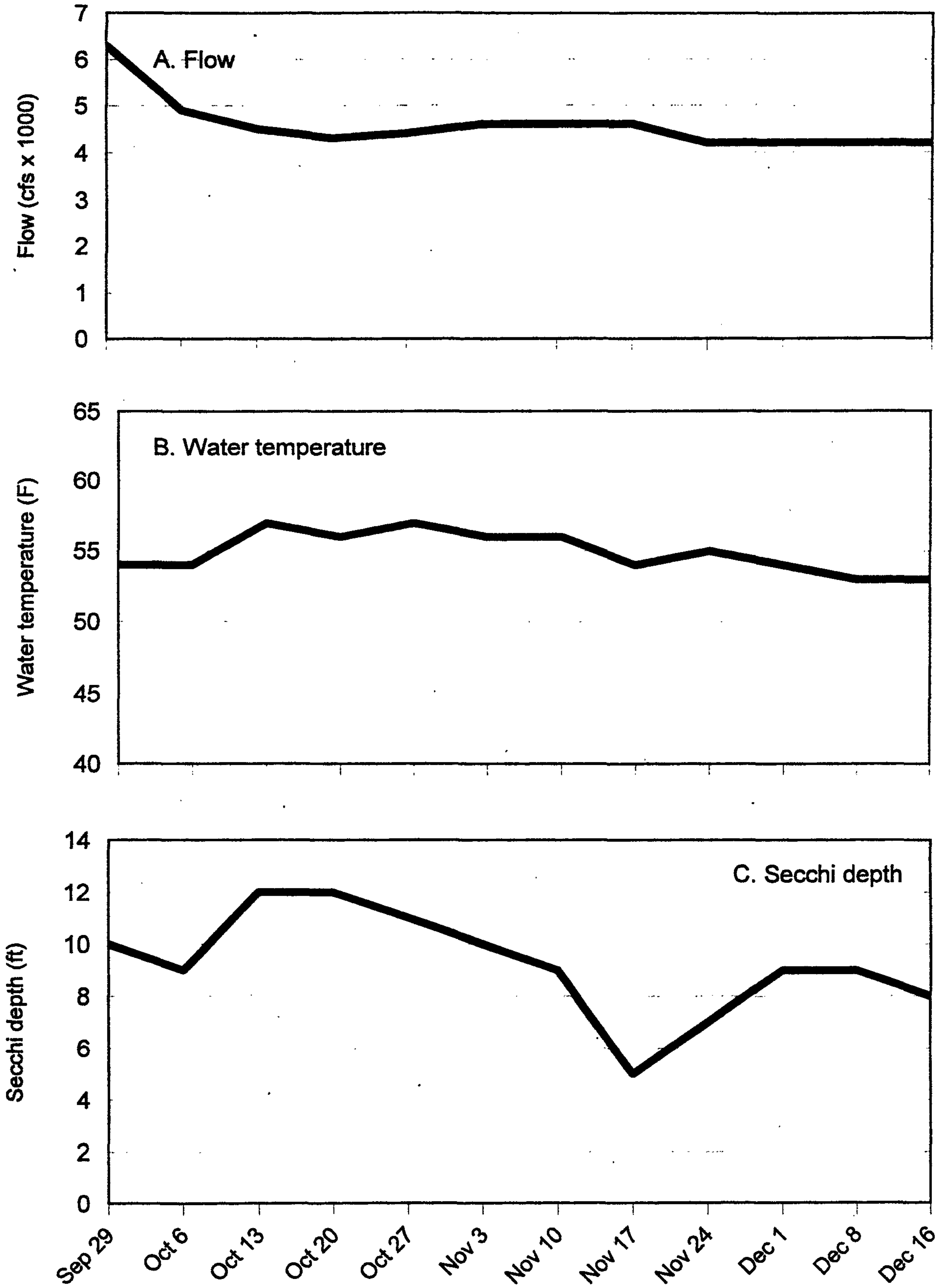

Figure 2. Mean daily flow (A), water temperature (B), and secchi depth (C), measured at Keswick Dam during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

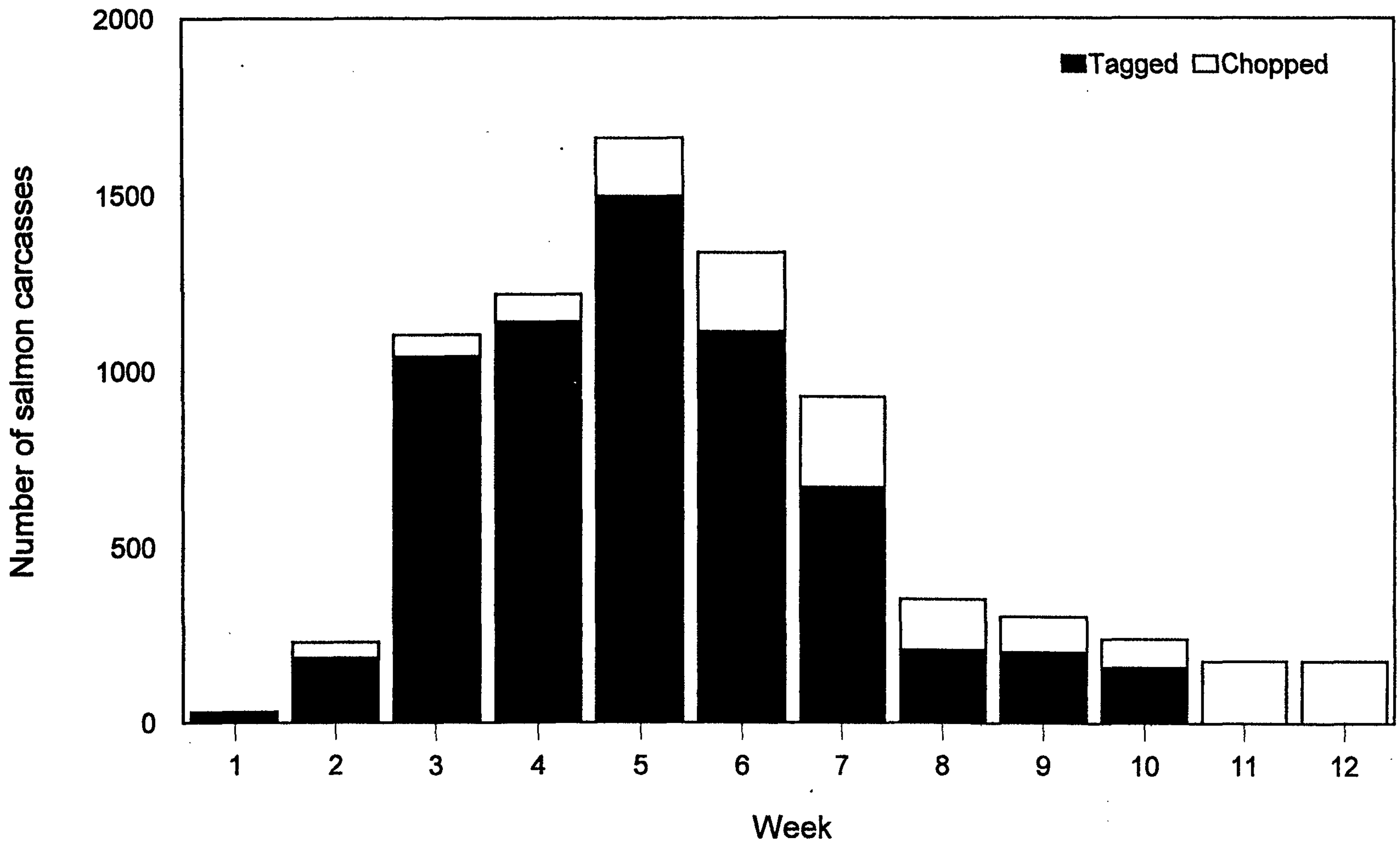

Figure 3. Weekly distribution of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

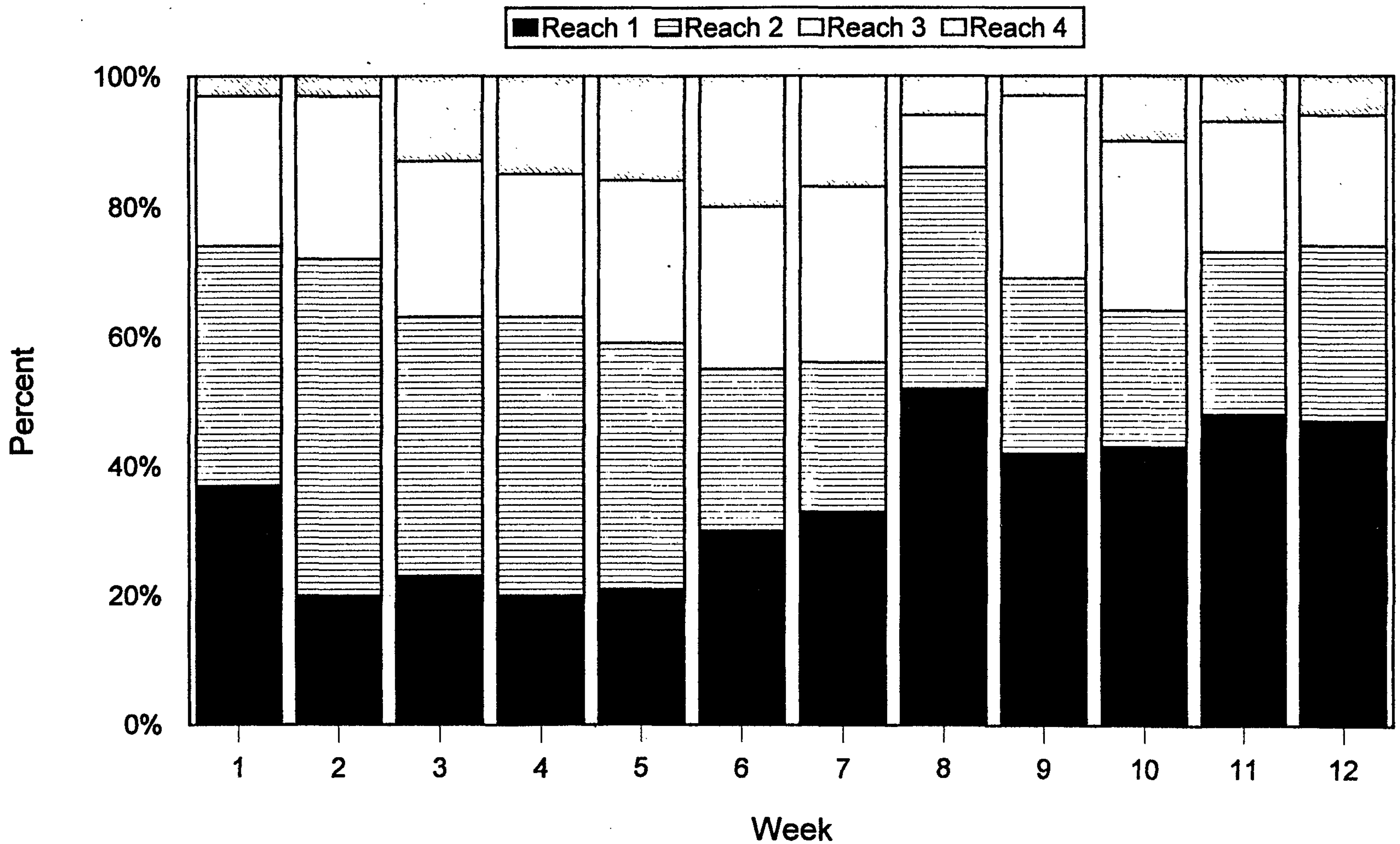

Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

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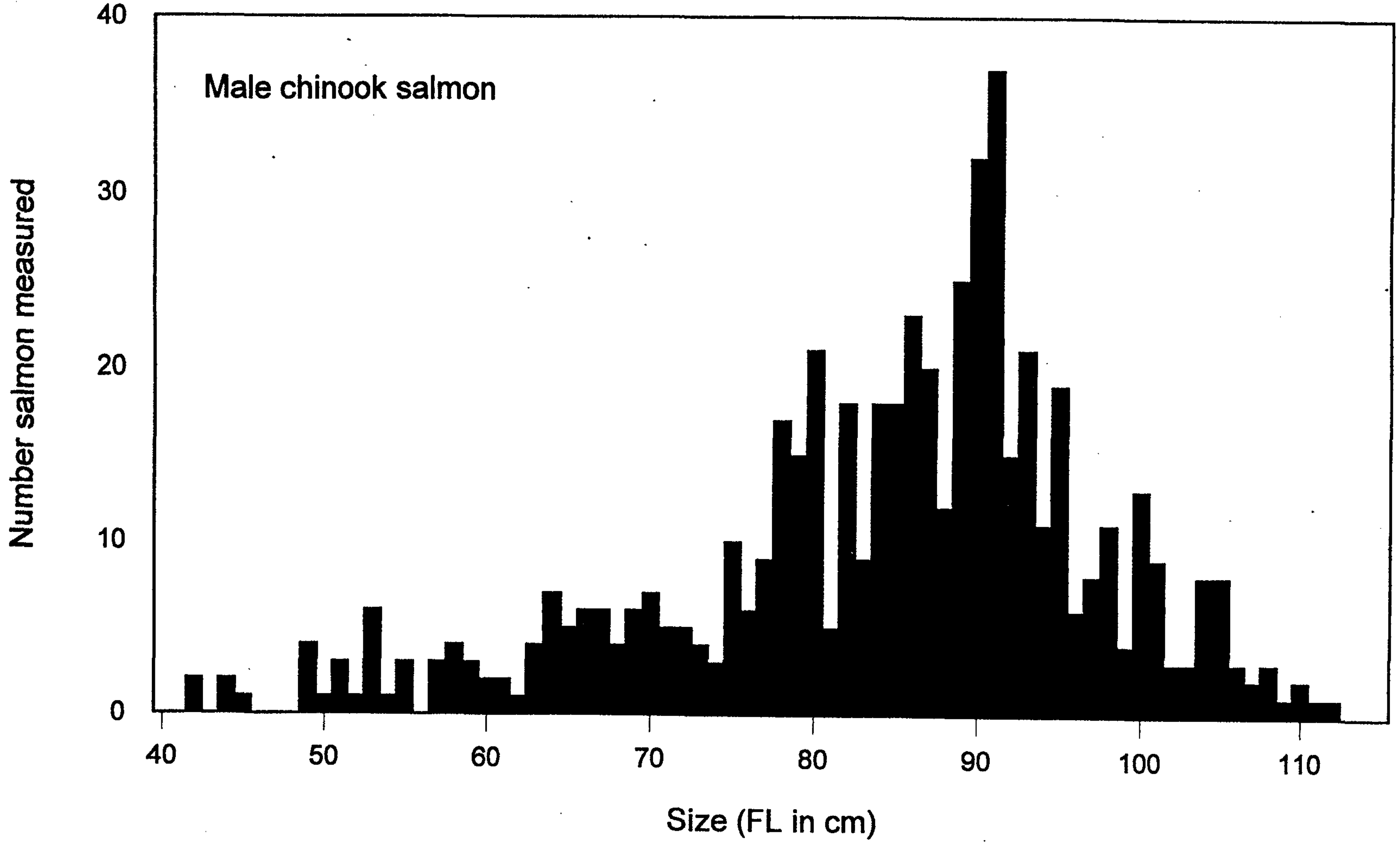

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1997.

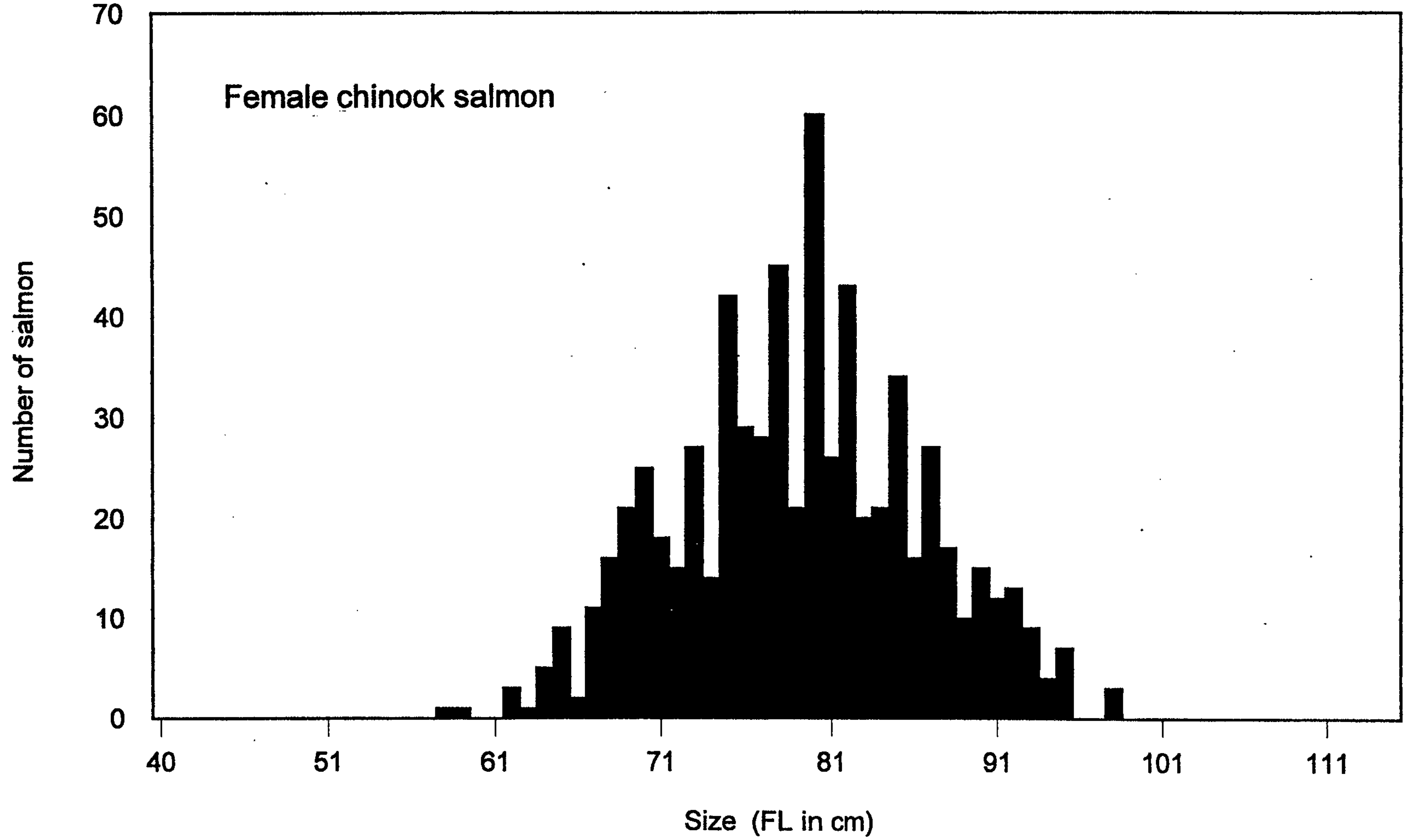

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1997.

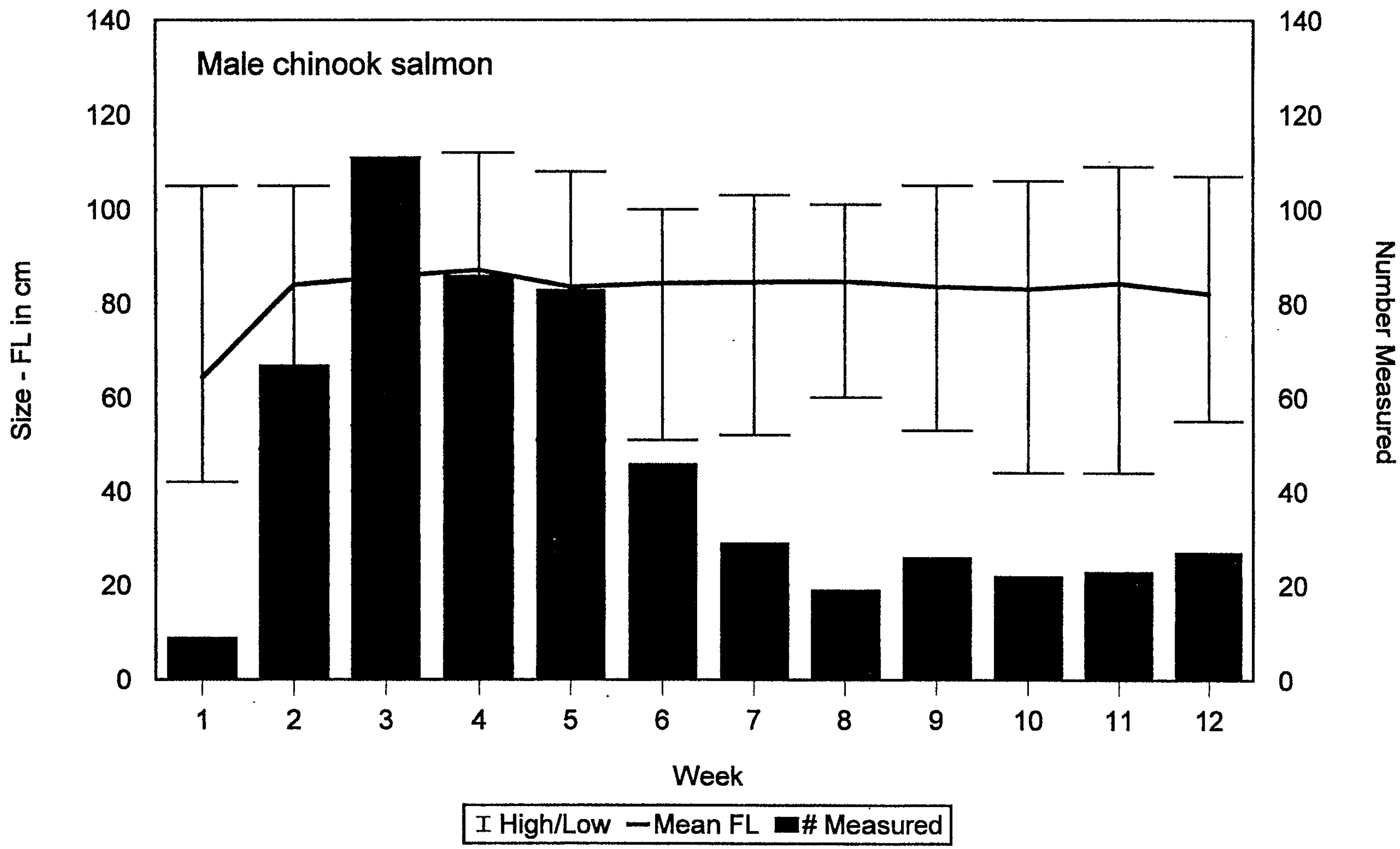

Figure 7. Mean size, size range, and number of male chinook salmon measured weekly during the 1997 upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

D-025596

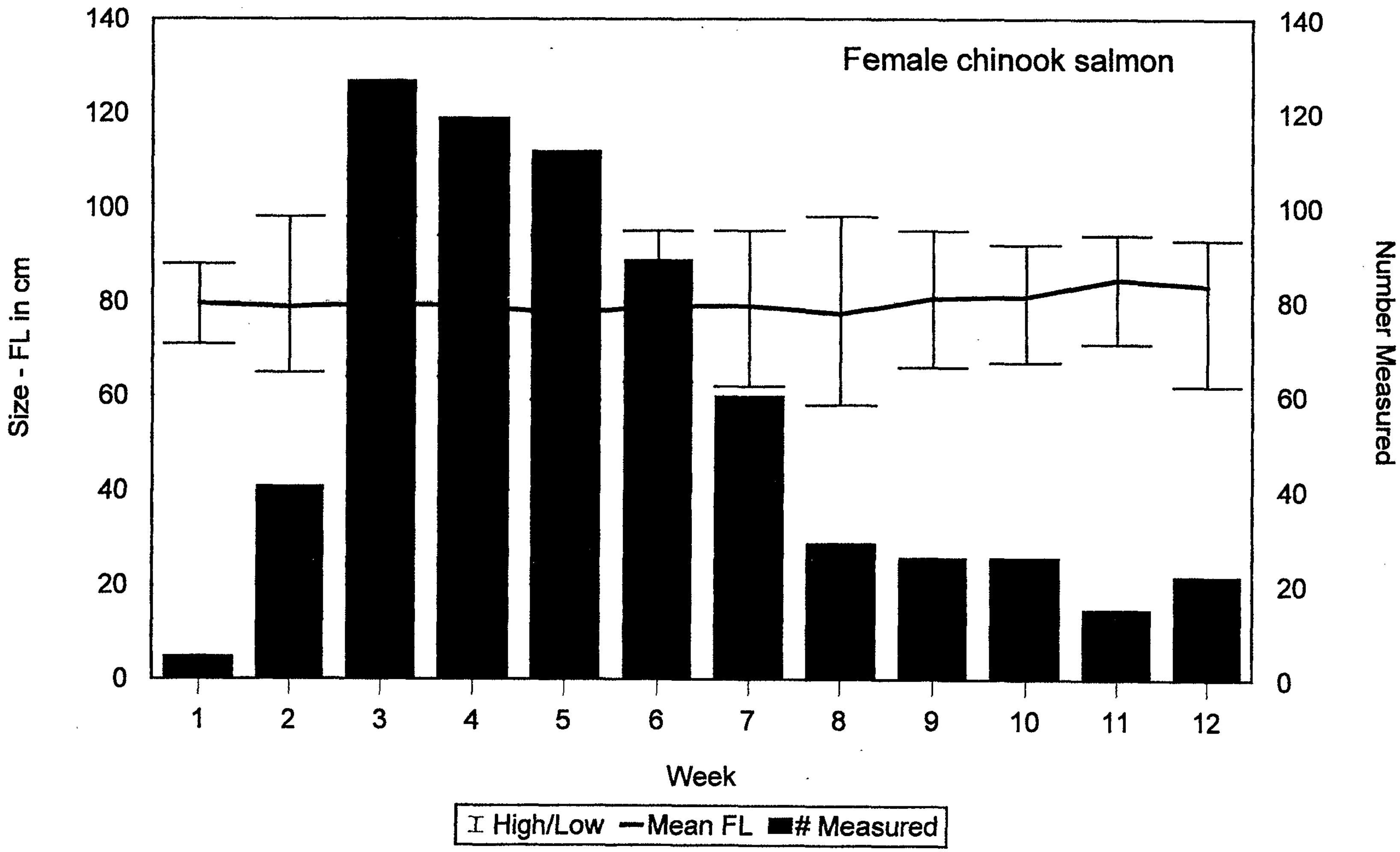

Figure 8. Mean size, size range, and number of female chinook salmon measured weekly during the 1997 upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

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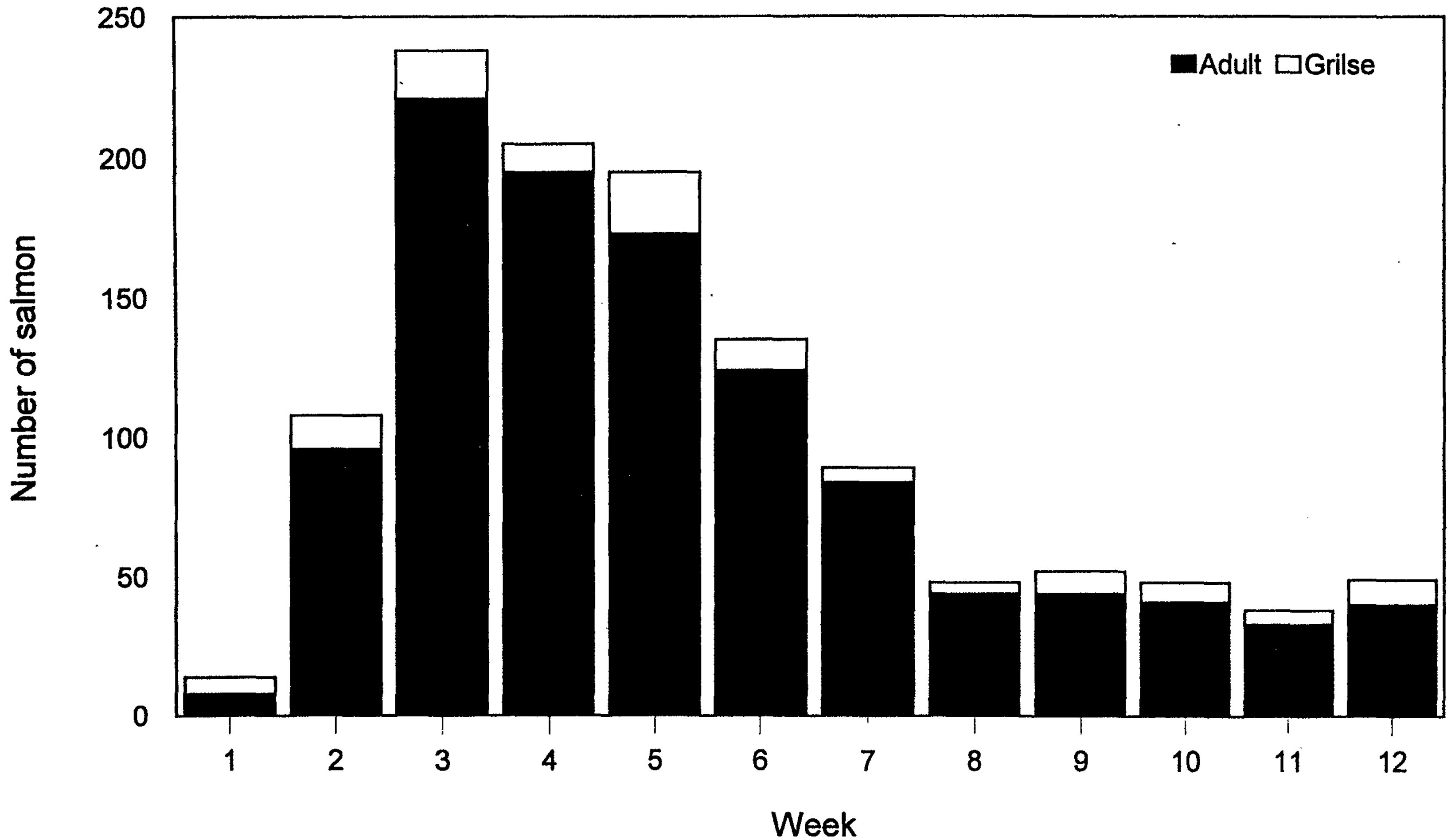

Figure 9. Age compostion of chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

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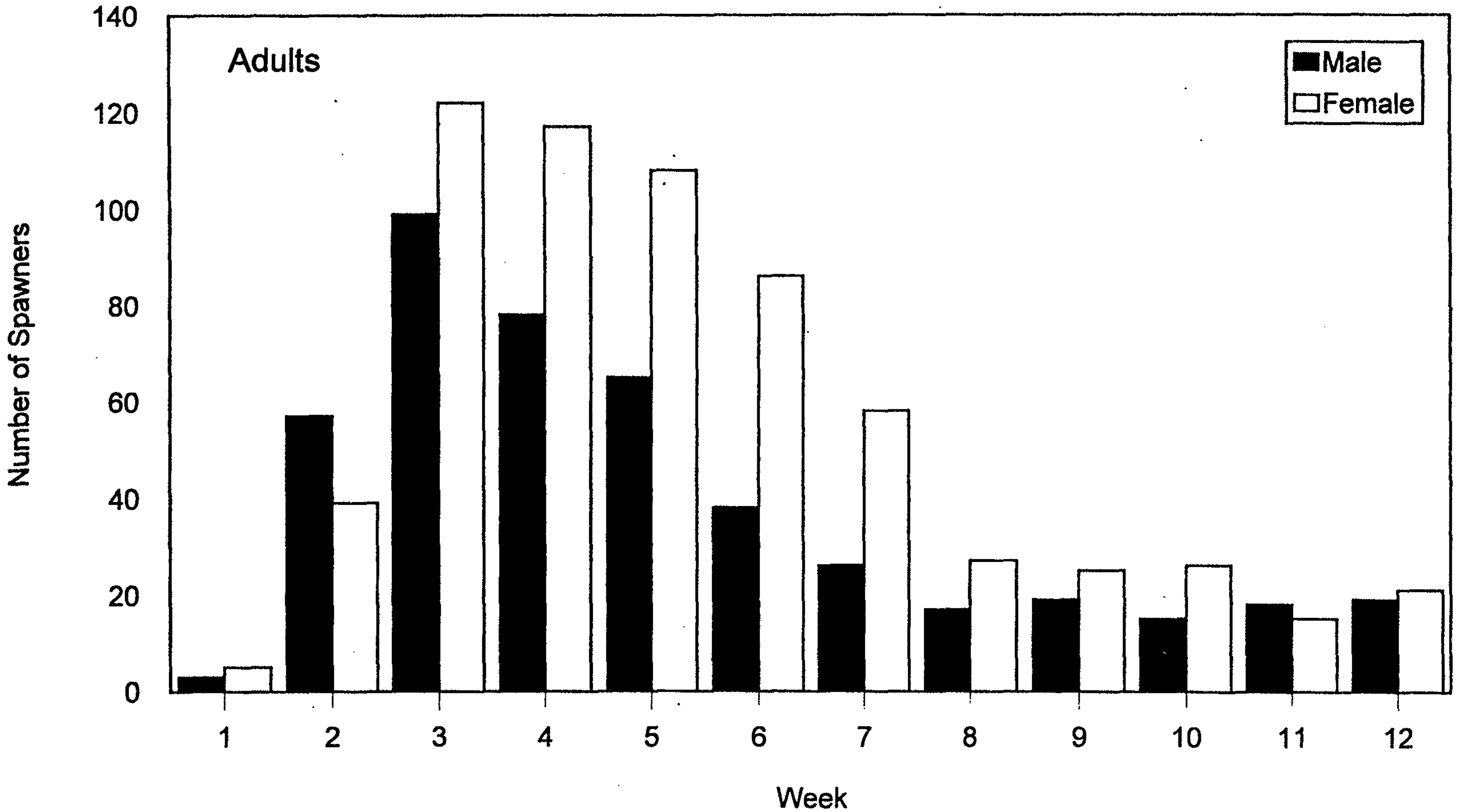

Figure 10. Weekly distribution of the sex of adult-sized chinook salmon measured during the 1996 upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

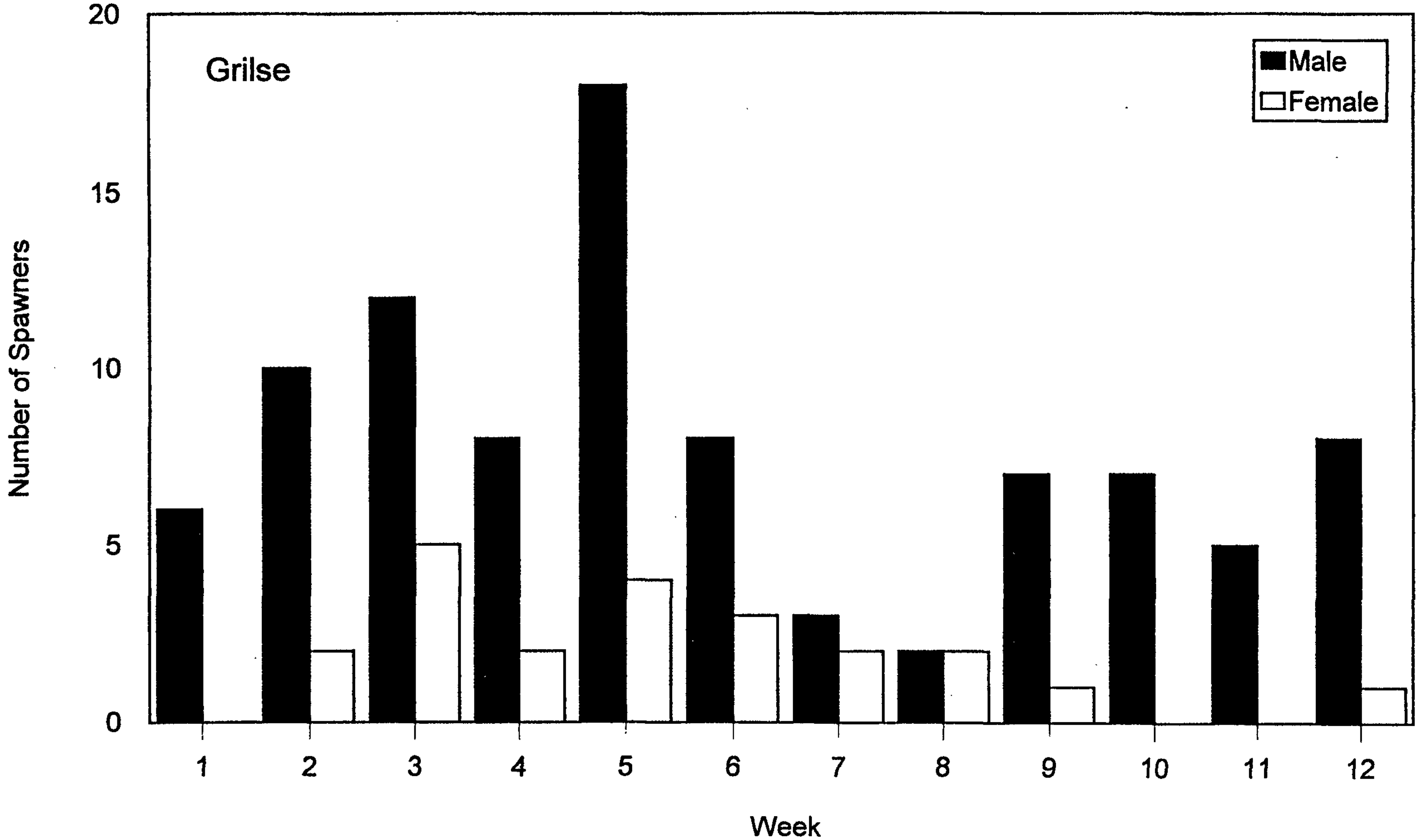

Figure 11. Weekly distribution of the sex of grilse-sized chinook salmon measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1997.

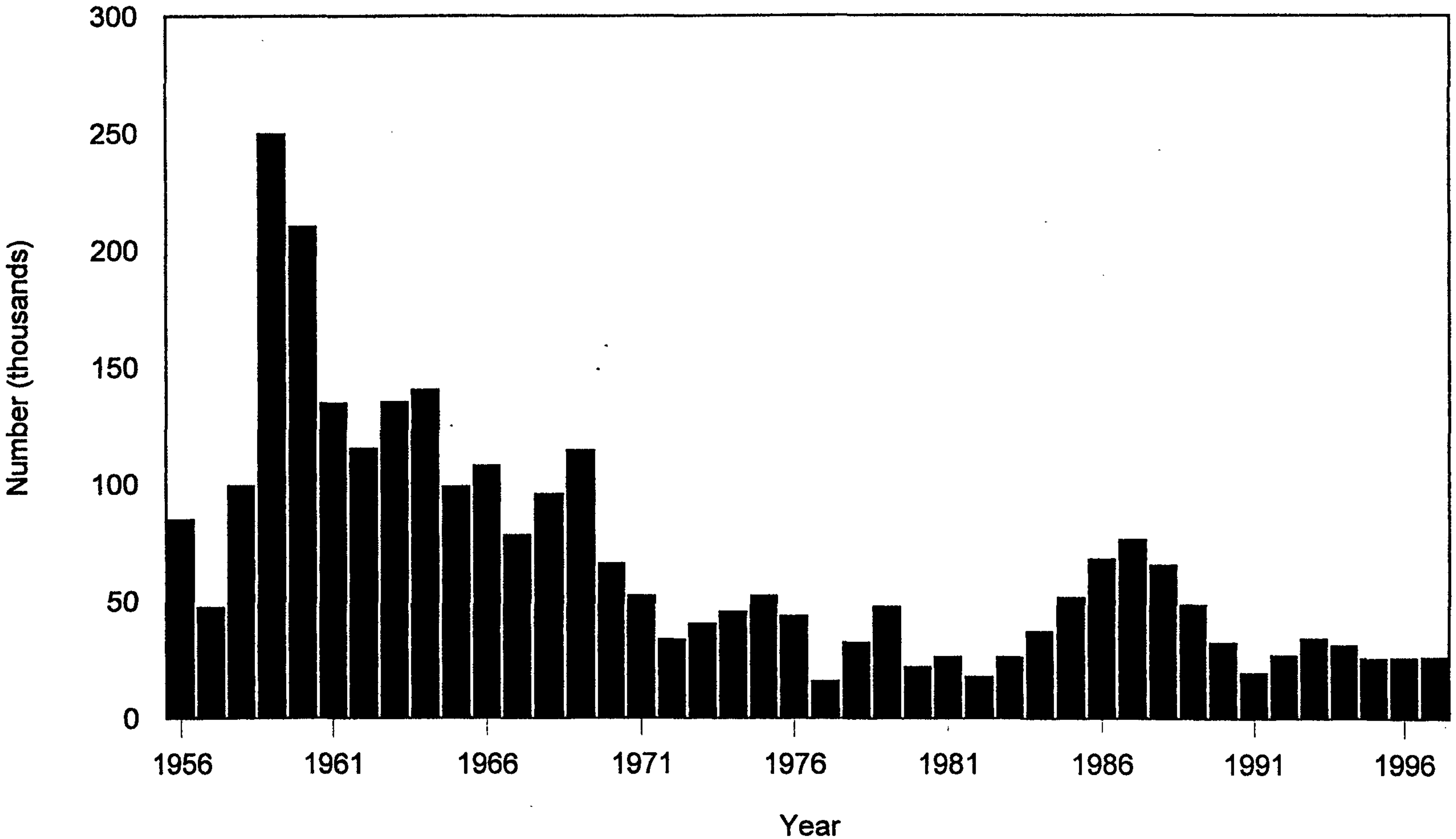

Figure 12. Summary of chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1956 - 1997).

D—025600

APPENDIX IV

Late-fall-run chinook salmon spawner survey report

CALIFORNIA DEPARTMENT OF FISH AND GAME
Environmental Services Division
Stream Evaluation Program

Upper Sacramento River Late-Fall-Run Chinook Salmon Escapement Survey December 1997 - May 1998 [1/]

by

Bill Snider
Bob Reavis
and
Scott Hill

July 1998

1/ This work was supported by funding provided by U.S. Fish and Wildlife, Service Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

SUMMARY

A late-fall-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey was conducted in the upper Sacramento River during winter and spring 1997 - 1998 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality and temporal and spatial distribution of spawning. The 1997-1998 survey is a part of a multi-year investigation by the DFG to determine salmon habitat requirements in the Sacramento River system. This was the second year we conducted a late-fall-run carcass survey on the upper Sacramento River. During the first survey, initiated in January 1996, high flows and extremely poor visibility forced suspension of the survey in late January. Poor survey conditions are typical during the late-fall-run spawning period. The duration of suitable survey conditions can range from less than a few days to several months.

Weekly surveys were conducted from 29 December 1997 through 1 May 1998. The surveys covered a 16.5-mile section of the Sacramento River located between Anderson-Cottonwood Irrigation District dam (ACID), at river mile (RM) 298.5, and Anderson River Park (RM 282.0). ACID dam is 3.5 miles downstream of Keswick Dam the upstream limit to salmon migration. Mean flow ranged from 4,200 cubic feet per second (cfs) during survey periods 1 and 2 (29 December 1997 through 7 January 1998), to 52,800 cfs in survey period 7 (9 - 10 February 1998). Mean water clarity ranged from 2 feet during survey periods 8 through 10 (19 February through 3 March 1998) and during survey period 13 (25 - 26 March 1998), to 12 feet during survey period 4 (20 - 22 January 1998). Mean water temperatures ranged from 47° F in survey period 13 (25 - 26 March) to 54° F in survey period 18 (30 April - 1 May 1998).

We examined 847 late-fall-run carcasses (182 fresh and 665 decayed), and measured (length) and sexed 179 fresh carcasses. Forty percent of the spawner population were male adults (>2-years old), 49% were female adults, 7% were male grilse (2-years old), and 4% were female grilse. We examined 91 fresh female carcasses for egg retention. Of these, 85 (93%) had completely spawned; 1 (1%) still contained a substantial number of eggs; and 5 (6%) were unspawned.

The number of carcasses observed was adversely affected by water clarity (Secchi disk readings ranged from only 2 to 4 feet during 12 weeks of the survey) and high flows (weekly averages were greater than 30,000 cfs or greater during 6 weeks of the survey). Peak carcass recovery occurred during the second survey period (5 - 7 January) when clarity was 11 ft..

The total spawner escapement of 9,717 (1,069 grilse and 8,648 adults) was estimated using the Peterson formula. The Peterson formula was used because there were no recoveries from 10 of the 17 tag groups released. The Schaefer and Jolley-Seber models are more credible but require that there be recoveries from most all of the tag groups released.

INTRODUCTION

The California Department of Fish and Game's (DFG) Stream Evaluation Program (STEP) conducted an intensive late-fall-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey on the upper Sacramento River during the winter-spring period of 1997-98 to estimate spawner abundance and distribution. This survey was carried out to fulfill the mandates of Section 3406(b)(1)(B) of the Central Valley Project Improvement Act (CVPIA), P.L. 102-575, which requires the Secretary of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers. Flow-need recommendations are to be provided to the Secretary by the U. S. Fish and Wildlife Service (FWS) after consultation with the DFG. In response to this Act, the FWS and the DFG have signed a "Cooperative Agreement" by which the FWS will fund the DFG to conduct studies to determine flow needs of salmonids in the upper Sacramento River.

The primary charge of STEP - to improve understanding of the relationships between anadromous salmonids and habitat in the upper Sacramento River - requires reliable estimates of the spawner population to help distinguish habitat versus population influences on temporal and spatial spawning distribution (Snider and McEwan 1992, Snider *et al.* 1993, Snider and Vyverberg 1995). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. Spawning density, redd superimposition, habitat use, and other parameters can be affected by both changes in habitat conditions (flow dependent) and spawner population size. A reliable population estimate developed concurrently with redd surveys allows this distinction. An intensive spawning escapement survey also provides additional baseline information on egg retention (pre-spawning mortality), age and sex composition, and behavior relative to habitat conditions and population size.

Carcass tag-and-recapture surveys have been regularly used to estimate fall-run chinook salmon spawner escapements in Central Valley tributary streams (e.g., American, Yuba, and Feather rivers). During these surveys, carcasses are tagged and released into running water for later recapture. This protocol was initially used in the Central Valley in 1973 to estimate the Yuba River escapement (Taylor 1974). This is the second year a carcass tag-and-recapture survey was conducted in the upper Sacramento River to estimate late-fall-run escapement. A late-fall-run carcass survey attempted in 1996, but was severely hampered by high flows.

Three models have been used by the DFG to estimate escapement based on carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1994). It has been used primarily when data are insufficient to allow calculation with the other models. It is occasionally used to calculate estimates for small spawner populations (e.g., recent upper Sacramento River winter-run populations). A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. The Schaefer and Jolly-Seber models have been used during the last 3 seasons to estimate fall-run salmon escapement for the upper Sacramento River (Snider *et. al.* 1997 and Snider *et. al.* 1996)

Based on Law's (1994) analysis, the Schaefer model will overestimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those typically observed in Central Valley tributaries. Similarly, based on Law's (1994) analysis, the Jolly-Seber model will slightly underestimate Central Valley spawner escapement. This model was first used to estimate escapement in the Central Valley in 1988. The Jolly-Seber model is more accurate when model assumptions are met and recovery rates are ≥10% (Boydstun 1994, Law 1994). Still, there is considerable disagreement about model use among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.)[1]. Law (1994) states that both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

METHODS

The 1998 late-fall-run salmon spawner escapement surveys were conducted from 29 December 1997 through 1 May 1998. The 16.5-mile-long stream segment from ACID dam (RM 298.5) downstream to Anderson River Park (RM 282; Figure 1) was divided into three reaches (Table 1). Each reach was surveyed once per week.

Table 1. Location of survey reaches during the upper Sacramento River late fall-run chinook salmon escapement survey, December 1997 - May 1998.

Reach	Location	River mile (length in miles)
1	ACID Dam to Cypress St. Bridge	298.5 - 295.0 (3.5)
2	Cypress St. Bridge to Bonnyview Bridge	295.0 - 292.0 (3.0)
3	Bonnyview Bridge to Anderson River Park	292.0 - 282.0 (8.0)

Surveys were primarily conducted using one boat with two observers per boat. The observers attempted to locate and collect carcasses as the boat traversed the river between the channel margins. Collected carcasses were checked for completeness (i.e., with the head intact) and previous tags. Complete, untagged carcasses were usually tagged by attaching a colored ribbon (to indicate survey period tagged) to the

1 Personal communication with Frank Fisher (DFG-Inland Fisheries Division, Red Bluff) and Fred Meyer (DFG Region 2, Sacramento (retired)).

jaw using a hog ring. Carcasses that were not tagged were chopped in half. Chopped carcasses included: i) those previously tagged, ii) those on shore in a "leathery condition"; and, iii) those in the lower end of Reach 3 (the most downstream reach) that would likely wash out of the survey area and never be recovered. Tagged carcasses were released into running water for recapture. Data collected to estimate population size included number tagged, number chopped, and number recovered.

All carcasses were examined for eye clarity and gill color to determine freshness. Carcasses were considered fresh if either eye was clear or gills were pink. Data collected from a subsample of the fresh carcasses included gender, fork length (FL) in centimeters, reach of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining; as partially spent if a substantial amount of the eggs remained; and unspent if the ovaries appeared nearly full of eggs. Carcasses were also examined for adipose-fin marks indicating presence of a coded-wire tag.

Our objective was to estimate the late-fall-run salmon natural escapement in the upper Sacramento River, preferably using the more accepted Schaefer or Jolly-Seber models. since there were no recoveries from 10 of the 17 released tag groups, these models could not be used. We instead used the Peterson model.

Flow measurements for each survey day were obtained from the Keswick gauge operated by the U.S. Geological Survey. Water temperature (grab sample) and water visibility (Secchi depth) were measured daily by the survey crew.

RESULTS AND DISCUSSION

A total of 847 carcasses was observed (Table 2). Mean flow ranged from 4,200 cubic feet per second (cfs) during the first and second survey periods (29 December 1997 - 7 January 1998) to 52,800 cfs during survey period 7 (9 - 10 February); flow was greater than 20,000 cfs during half of the periods surveyed (Table 2, Figure 2). Mean temperature ranged from 47° F during survey period 13 (25 - 56 March 1998) to 54° F during survey period 18 (30 April - 1 May 1998) (Table 2, Figure 2). Water clarity (Secchi depth) ranged from 2 ft in survey period 13 to 12 ft in survey period 4, and averaged 4 ft or less in 12 of the 18 survey periods surveyed (Table 2, Figure 2).

Temporal Distribution

Most (58%) of the 847 carcasses observed during the survey were seen during the first 2 survey periods (Table 2 and Figure 3). After the second period, poor survey conditions (high flows and reduced water clarity) caused by heavy rains, likely resulted in fewer carcasses being counted.

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Table 2. General survey information for the upper Sacramento River late-fall-run chinook salmon escapement survey, December 1997 - May 1998.

Survey period	Survey dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (^{o}F)[2/]	Carcass count[3/]	
					Fresh	Decayed
1	Dec 29 - 31 (1997)	4,200	10	51	60	160
2	Jan 5 - 7	4,200	8	48	61	211
3	Jan 12 - 14	5,100	6	48	25	66
4	Jan 20 - 22	29,500	12	50	7	38
5	Jan 26 - 28	31,000	11	49	6	14
6	Feb 2 - 5	29,400	3	48	3	85
7	Feb 9 - 10	52,800	3	48	2	6
8	Feb 19 - 20	30,000	2	48	5	26
9	Feb 23 - 24	36,200	2	48	1	5
10	Mar 2 - 3	38,700	2	48	0	1
11	Mar 11 - 12	11,600	3	48	1	13
12	Mar 18 - 20	8,900	4	49	1	3
13	Mar 25 - 26	44,000	2	47	1	0
14	Apr 2	23,800	4	48	1	5
15	Apr 7 - 9	6,800	4	49	0	9
16	Apr 15 - 17	6,000	4	49	2	11
17	Apr 23 - 24	10,000	5	51	0	1
18	Apr 30 - May 1	10,900	4	54	5	11
				Totals	182	665

1/ Mean flow during days sampled as measured at Keswick Dam by U.S. Bureau of Reclamation.
2/ Mean of daily measurements taken by survey crews.
3/ Includes both adults and grilse.

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Spatial Distribution

The distribution of the total carcasses observed per reach was 62% in Reach 1, 19% in Reach 2, and 19% in Reach 3 (Table 3 and Figure 4).

Size Distribution

A total of 179 carcasses was measured (Table 4). Mean size was 84.0 cm FL. Size ranged from 42 to 112 cm FL. Male salmon (n = 84) averaged 86.0 cm FL (range: 42 - 112 cm FL) (Figure 5). Female salmon (n = 95) averaged 82.2 cm FL (range: 50 - 100 cm FL) (Figure 6). The weekly mean size for males ranged from 71.0 to 96.0 cm FL (Figure 7). Weekly mean size for females ranged from 72.0 to 89.0 cm FL (Table 4 and Figure 8).

Length-frequency distributions were used to define a general size criterion distinguishing grilse (2-year-old salmon) and adults (>2-year-old salmon) for each sex (Figures 5 and 6). Both male (n=12) and female (n=8) grilse were defined as salmon ≤70 cm FL (Table 5). Male grilse averaged 59.6 cm FL (range: 42 - 70 cm FL, SD=9.3); male adults (n=72) averaged 90.4 cm FL (range: 71 - 112 cm FL, SD=9.7). Female grilse averaged 64.4 cm FL (range: 50 - 70 cm FL, SD=7.0); female adults (n=87) averaged 83.8 FL (range: 71 - 100 cm FL, SD=6.7).

Grilse comprised 11% (20) of the 179 measured carcasses (Table 6). The greatest numbers of grilse (13) were observed in the first 2 survey periods (29 December 1997 - 7 January 1998) (Figure 9). Adults comprised 89% (159) of the carcasses measured. The greatest number of adults (108) was also observed during survey periods 1 and 2.

Sex Composition

Males comprised 45% (n = 72) of the fresh adult carcasses examined and females comprised 55% (n=87)(Table 7). Males comprised 60% (n=12) and females comprised 40% (n=8) of the fresh grilse observed. Females comprised 53% (n=95) and males comprised 47% (n=84) of all fresh carcasses measured.

The female to male ratio for adult spawners was nearly 1.2:1 (87:72) (Table 7 and Figure 10). Females made up at least half of the adult population throughout the survey period. Male grilse were only observed during the first 3 survey periods while female grilse observations were scattered throughout the survey (Figure 11).

Table 3. Distribution of carcass (adults and grilse) observed during the upper Sacramento River late-fall-run chinook salmon escapement survey, September - December 1997.

Survey period	Reach 1		Reach 2		Reach 3	
	M[1/]	C[2/]	M	C	M	C
1	131	1	45	1	42	0
2	132	32	33	15	49	11
3	38	8	28	8	6	3
4	37	5	1	0	2	0
5	7	1	7	2	2	2
6	43	26	0	2	10	7
7	1	0	0	0	5	2
8	19	4	6	2	0	0
9	5	0	0	1	0	0
10	0	0	0	0	0	1
11	5	1	0	1	4	3
12	3	0	1	0	0	0
13	1	0	0	0	0	0
14	2	1	0	3	0	0
15	3	2	2	1	1	0
16	5	1	2	0	3	2
17	1	0	0	0	0	0
18	0	6	0	4	0	6
Total	433	88	125	40	124	37

1/ Number of carcasses tagged.
2/ Number of untagged carcasses chopped.

Table 4. Size and sex statistics for fresh late-fall-run chinook salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

Survey period	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm)		Number measured	Length (FL in cm)		Number measured	Length (FL in cm)	
		Mean	Range		Mean	Range		Mean	Range
1	60	83.6	42-112	36	85.9	42-112	24	84.3	69-100
2	61	82.1	47-111	31	86.2	47-111	30	80.6	69-96
3	22	83.6	60-95	11	85.4	68-94	11	82.3	60-95
4	7	80.7	69-93	0	-	-	7	80.7	69-93
5	7	85.3	79-91	1	91.0	-	6	85.6	79-87
6	3	81.3	67-89	0	-	-	3	81.3	67-89
7	2	91.0	87-95	1	95.0	-	1	87.0	-
8	5	81.6	50-100	2	96.0	92-100	3	72.0	50-85
9	1	87.0	-	0	-	-	1	87.0	-
10	0	-	-	0	-	-	0	-	-
11	1	87.0	-	0	-	-	1	87.0	-
12	1	91.0	-	0	-	-	1	91.0	-
13	1	87.0	-	0	-	-	1	87.0	-
14	1	87.0	-	0	-	-	1	87.0	-
15	0	-	-	0	-	-	0	-	-
16	2	80.0	-	1	71.0	-	1	89.0	-
17	0	-	-	0	-	-	0	-	-
18	5	78.2	61-91	1	73.0	-	4	79.5	61-91
Total (mean)	179	(84.0)	42-112	84	(86.0)	42-112	95	(82.2)	50-100

Table 5. Summary of adult and grilse sizes and numbers by sex for carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	8	87	12	72
Mean FL (cm)	64.4	83.8	59.6	90.4
Range FL (cm)	50-70	71-100	42-70	71-112
S D	7.0	6.7	9.3	9.7

Table 6. Age composition (grilse and adult) of carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

	Adults		Grilse	
Survey period	Number	Percent	Number	Percent
1	52	87	8	13
2	56	92	5	8
3	19	86	3	14
4	6	86	1	14
5	7	100	0	0
6	2	67	1	33
7	2	100	0	0
8	4	80	1	20
9	1	100	0	0
10	0	-	0	-
11	1	100	0	0
12	1	100	0	0
13	1	100	0	0
14	1	100	0	0
15	0	-	0	-
16	2	100	0	0
17	0	-	0	-
18	4	80	1	20
Total(mean)	159	(89)	20	(11)

Table 7. Sex composition of late-fall-run chinook salmon grilse and adults carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

Survey period	Adults				Grilse*			
	Male		Female		Male		Female	
	Number	%	Number	%	Number	%	Number	%
1	29	51	23	49	7	88	1	12
2	27	48	29	52	4	80	1	20
3	10	53	9	47	1	33	2	67
4	0	0	6	100	0	0	1	100
5	1	14	6	86	0	-	0	-
6	0	0	2	100	0	0	1	100
7	1	50	1	50	0	-	0	-
8	2	50	2	50	0	0	1	100
9	0	0	1	100	0	-	0	-
10	0	-	0	-	0	-	0	-
11	0	0	1	100	0	-	0	-
12	0	0	1	100	0	-	0	-
13	0	0	1	100	0	-	0	-
14	0	0	1	100	0	-	0	-
15	0	-	0	-	0	-	0	-
16	1	50	1	50	0	-	0	-
17	0	-	0	-	0	-	0	-
18	1	25	3	75	0	0	1	100
Total (mean)	72	(45)	87	(55)	12	(60)	8	(40)

• Based on length-frequency distributions grilse are defined as ≤ 70 cm FL.

Spawning Success

Ninety-one females were examined for egg retention (Table 8). Ninety-three percent (85) had completely spawned, 1% (1) had only partially spawned, and 6% (5) had not spawned. At least 75% of the females checked per survey period had completely spawned.

Coded-wire-tag Recovery Data

Two of the observed carcasses contained coded-wire tags. Both were from tag-code group # 05-36-20 indicating they were 1994 brood year late-fall run chinook salmon released from Coleman National Fish Hatchery. One carcass was a 89.0 cm FL male that was recovered on 12 January 1998, and the other was a 77.0 cm FL female that was recovered on 7 January 1998.

Population Estimates

Carcasses were recovered from only 5 of the 16 tag groups precluding use of either the Schaefer or Jolly-Seber models. As such, both fresh and decayed adult carcasses data were combined to calculate an escapement estimate using the Peterson model. The adult escapement estimate of 8,648 adults was calculated using the following adjusted Petersen formula (3.7) as described by Ricker (1975)[2]: The adult estimate was then divided by 0.89 (portion of adults as determined from fresh carcass subsample) yielding a total population estimate of 9,717 (8,648 adult and 1,069 grilse). It should be noted that Law (1994) concluded the Petersen model consistently and substantially overestimated the total population compared to either the Schaefer or Jolly-Seber models.

The 1998 escapement of 9,717 is less than the 1967 - 1992 average of 14,159 for the section of stream from Keswick Dam to Red Bluff Diversion Dam (RBDD) (Table 12 and Figure 12). These estimates for the 1967 through 1992 period were based on RBDD ladder counts. Changes in operation of RBDD has eliminated the opportunity to count late-fall run since 1993.

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$$N=\frac{(M+1)(C+1)}{(R+1)}$$

Where, N = estimated spawning population for survey period,
M = number of carcasses marked during survey,
C = total number of carcasses examined during survey, and
R = number of marked carcasses recovered during survey.

Table 8. Summary of spawning completion (egg retention) determined from fresh female salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

Survey period	No. females measured	No. females checked for egg retention	Number spawned (%)	Number partially spawned (%)	Number unspawned (%)
1	24	23	20(87)	1(4)	2(9)
2	30	28	27(96)	0(0)	1(4)
3	11	11	10(91)	0(0)	1(9)
4	7	7	7(100)	0(0)	0(0)
5	6	6	6(100)	0(0)	0(0)
6	3	3	3(100)	0(0)	0(0)
7	1	1	1(100)	0(0)	0(0)
8	3	2	2(100)	0(0)	0(0)
9	1	1	1(100)	0(0)	0(0)
10	0	0	-	-	-
11	1	1	1(100)	0(0)	0(0)
12	1	1	1(100)	0(0)	0(0)
13	1	1	1(100)	0(0)	0(0)
14	1	1	1(100)	0(0)	0(0)
15	0	0	-	-	-
16	1	1	1(100)	0(0)	0(0)
17	0	0	-	-	-
18	4	4	3(75)	0(0)	1(25)
Total (mean)	95	91	85(93)	1(1)	5(6)

Table 9. Summary of tagging and recapture of salmon carcasses (fresh and decayed) observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

Survey period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
1	Dec 30-31	200	20	199	19	-
2	Jan 5-7	256	16	204	10	38*(1)
3	Jan 12-14	83	8	64	8	15(2), 3(1)
4	Jan 20-22	44	1	39	1	1(2)
5	Jan 26-28	19	2	15	1	1(4)
6	Feb 2-5	83	5	49	4	1(5), 1(4), 1(3)
7	Feb 9-10	8	0	6	0	0
8	Feb 19-20	30	1	24	1	0
9	Feb 23-24	6	0	5	0	2(8)
10	Mar 2-3	1	0	0	0	0
11	Mar 11-12	13	1	8	1	0
12	Mar 18-20	4	0	4	0	0
13	Mar 25-26	1	0	1	0	0
14	Apr 2	5	1	2	0	0
15	Apr 7-9	9	0	6	0	0
16	Apr 15-17	13	0	10	0	0
17	Apr 23-24	1	0	1	0	0
18	Apr 30 -May 1	14	2	0	0	0
Totals		790	57	637	45	63

* Includes one grilse

Table 10. Summary of tagging and recapture of late-fall-run chinook salmon carcasses (fresh) observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

Survey period	Date	Number observed*		Number tagged**		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
1	Dec 30-31	200	20	53	6	-
2	Jan 5-7	256	16	49	2	8+(1)
3	Jan 12-14	83	8	20	2	2(2)
4	Jan 20-22	44	1	6	0	0
5	Jan 26-28	19	2	13	0	0
6	Feb 2-5	83	5	3	0	1(5)
7	Feb 9-10	8	0	2	0	0
8	Feb 19-20	30	1	4	1	0
9	Feb 23-24	6	0	1	0	0
10	Mar 2-3	1	0	0	0	0
11	Mar 11-12	13	1	1	0	0
12	Mar 18-20	4	0	1	0	0
13	Mar 25-26	1	0	0	0	0
14	Apr 2	5	1	1	0	0
15	Apr 7-9	9	0	0	0	0
16	Apr 15-17	13	0	2	0	0
17	Apr 23-24	1	0	0	0	0
18	Apr 30 -May 1	14	2	0	0	0
Totals		790	57	156	11	11

* Includes total carcasses observed.
** Includes only tagged fresh carcasses.
\+ Includes one grilse.

Table 11. Annual late-fall-run chinook salmon escapement estimates (adults and grilse) for upper Sacramento River from Keswick Dam to RBDD, 1956 - 1998. (Data provided by Frank Fisher, DFG, Red Bluff).

Year	Total	Year	Total
1967	37,208	1983	13,274
1968	34,733	1984	5,907
1969	37,178	1985	7,660
1970	19,190	1986	6,710
1971	14,323	1987	14,443
1972	31,553	1988	10,683
1973	22,204	1989	9,875
1974	6,445	1990	6,921
1975	16,663	1991	6,531
1976	15,280	1992	10,371
1977	9,090	1993	no est.
1978	8,880	1994	no est.
1979	8,740	1995	no est.
1980	7,747	1996	no est.
1981	1,597	1997	no est.
1982	1,141	1998	9,717*

* Based on carcass counts.

CONCLUSIONS AND RECOMMENDATIONS

1. Flows in excess of 30,000 cfs and water clarity 3 ft or less greatly hampered carcass recovery. As a result, the temporal distribution (Table 2) may not accurately reflect the temporal spawning distribution of this race. The February carcass counts would have likely been considerable greater under more optimal recovery conditions.

2. There may have been several peaks in spawning activity during the January to May period that would likely have been observed under more stable flow and better water clarity conditions.

3. Surveys should be continued assuming conditions for survey could improve (e.g., during a dry year) to more precisely determine: (i) the length of the period this run spawns; (ii) if there is one clearly defined period this ran spawns or are there a series of peaks; (iii) the appropriateness of categorizing salmon spawning during the January through May period as late-fall run.

ACKNOWLEDGEMENTS

The California Department of Fish and Game recognizes the efforts of Chris Cox, Jon Ferguson, John Galos, Jeffrey Jahn, James Lyons, Warren Nichols, Mike Spiker, and Jonathan Sutliff. Their efforts in the collection of field data are greatly appreciated. The data collection was funded by the FWS as a part of a cooperative agreement with the DFG as authorized by the CVPIA (P.L. 102-575).

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FIGURES

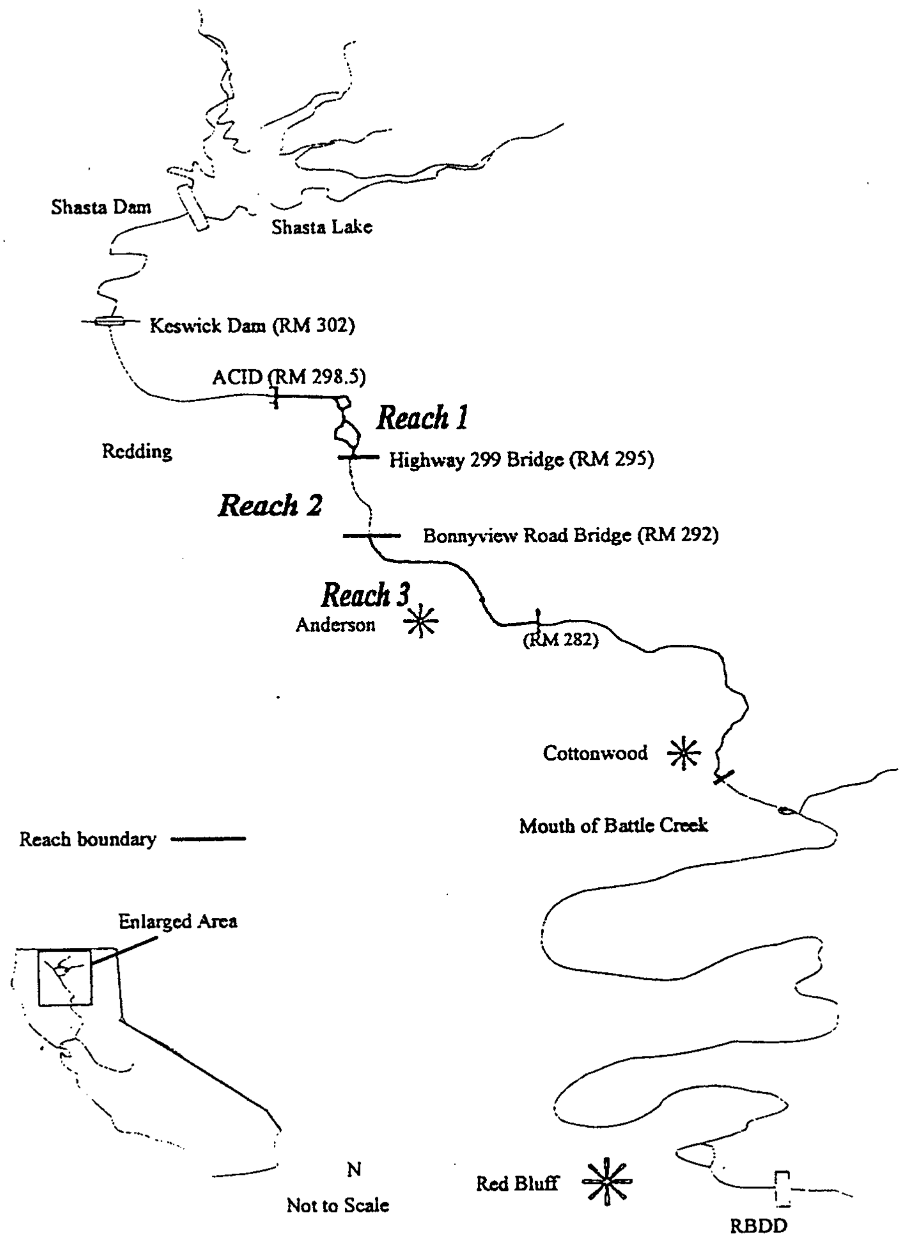

Figure 1. Location of sampling reaches in the upper Sacramento River late- fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

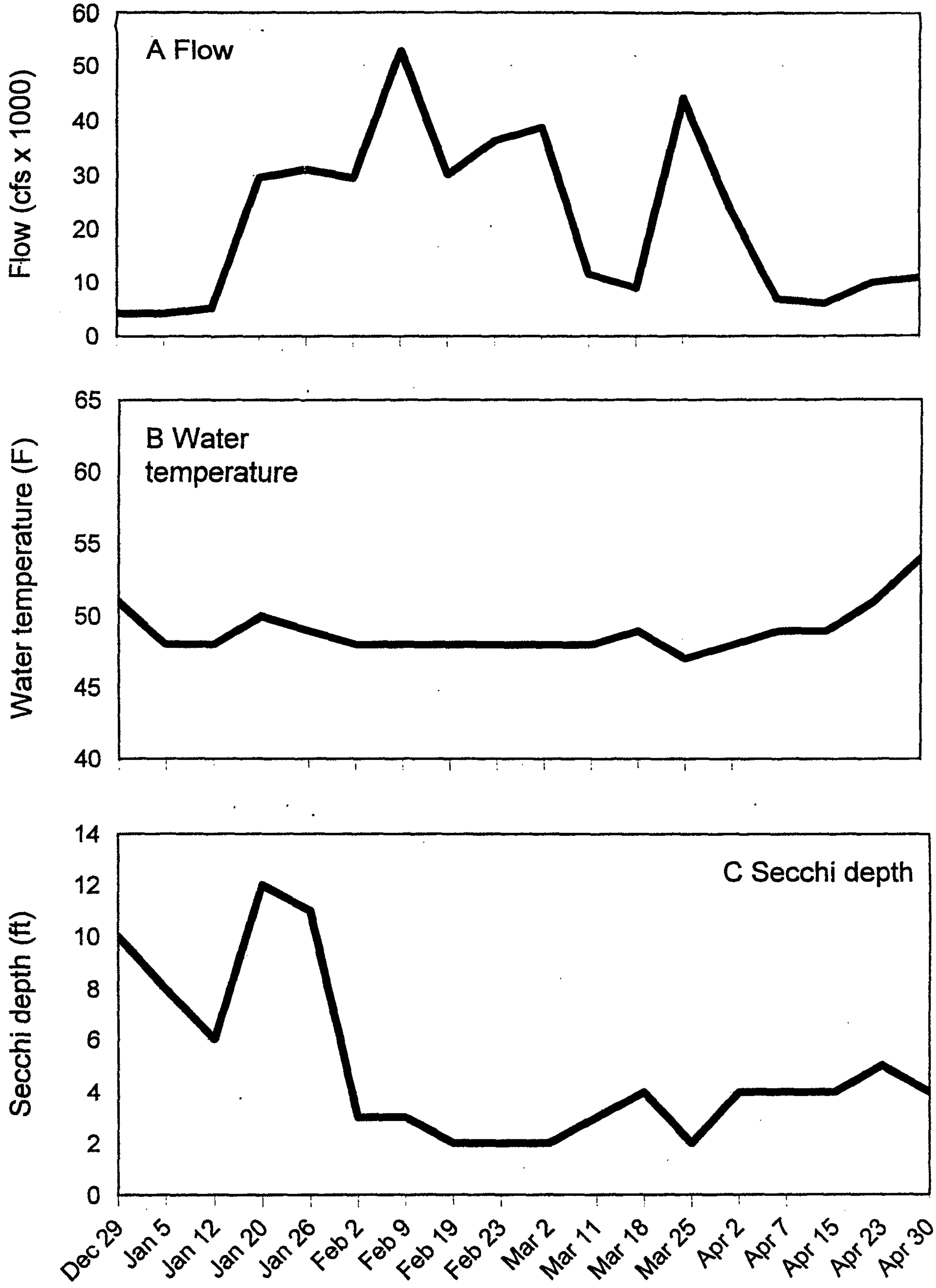

Figure 2. Mean daily flow (A) measured at Keswick Dam, water temperature (B) and secchi depth (C) during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

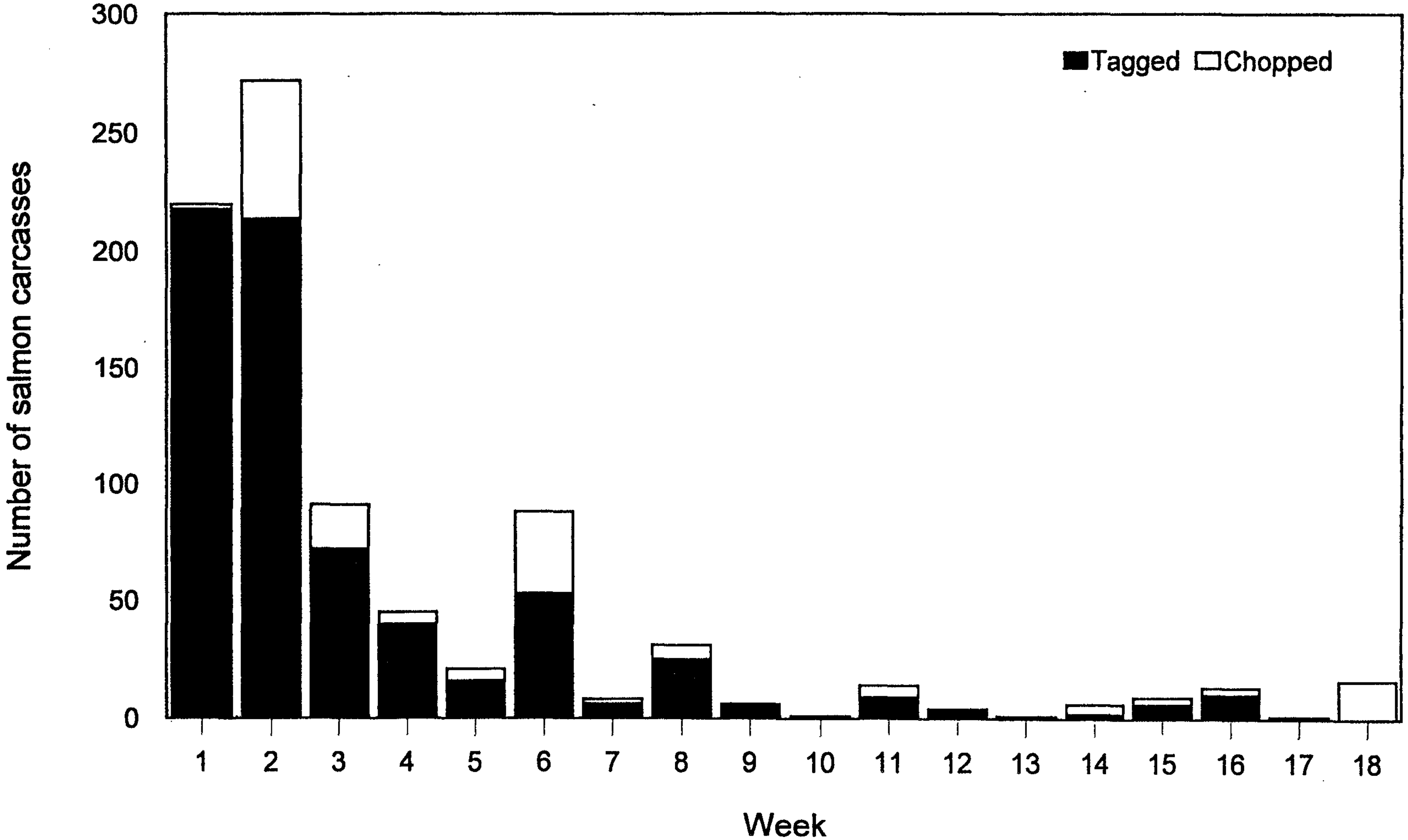

Figure 3. Weekly distribution of both fresh and decayed carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

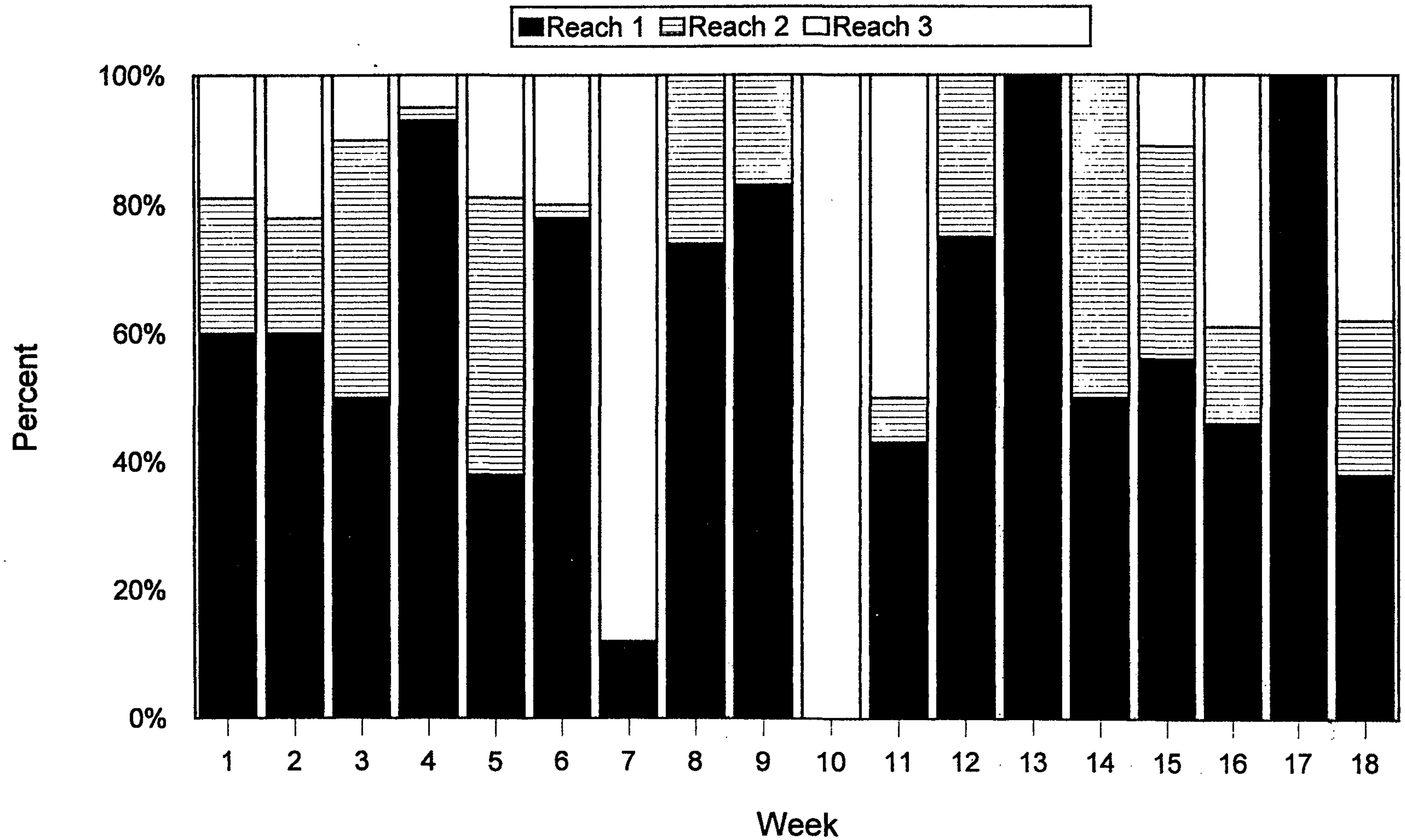

Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

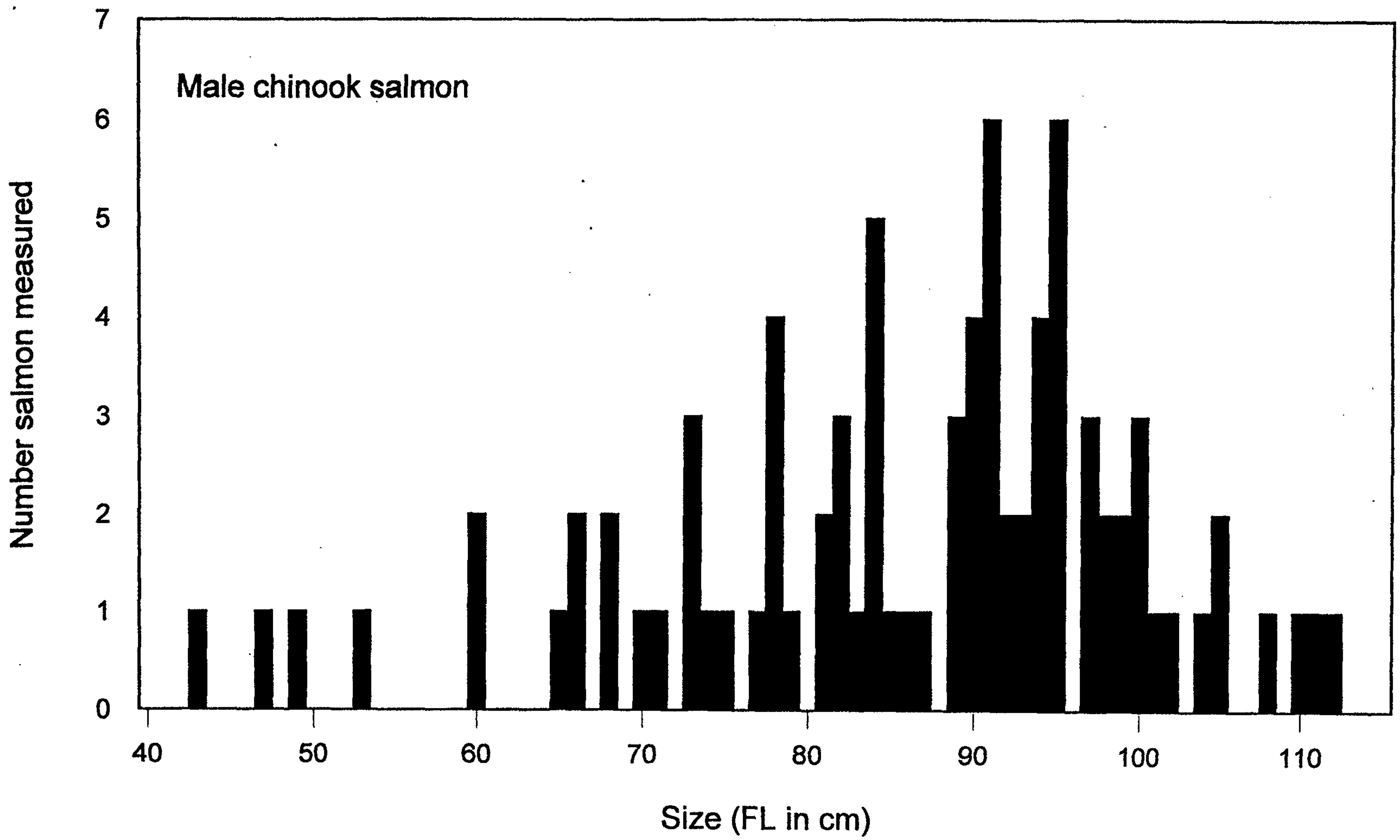

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River late-fall-run spawner escapement survey, December 1997 - May 1998.

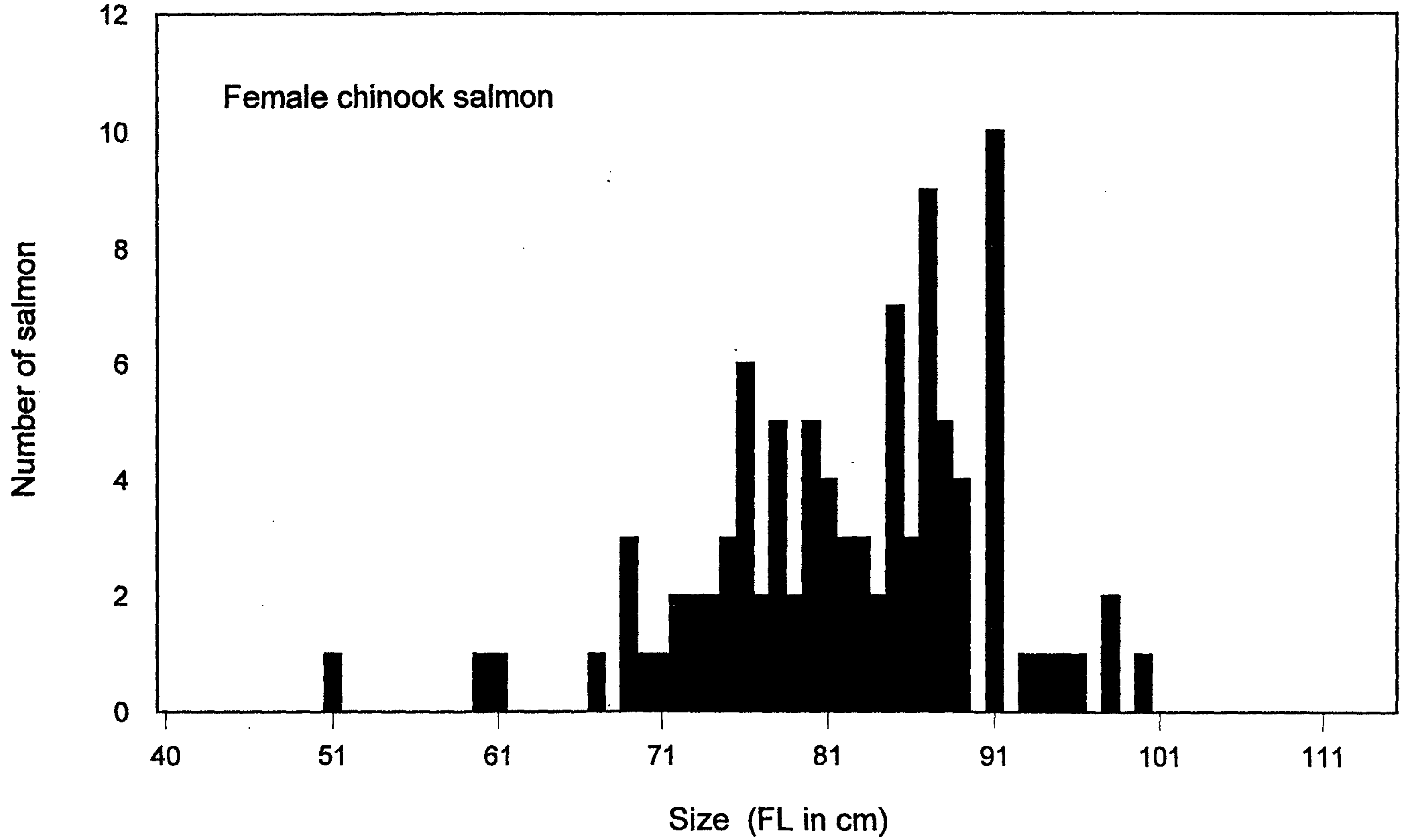

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

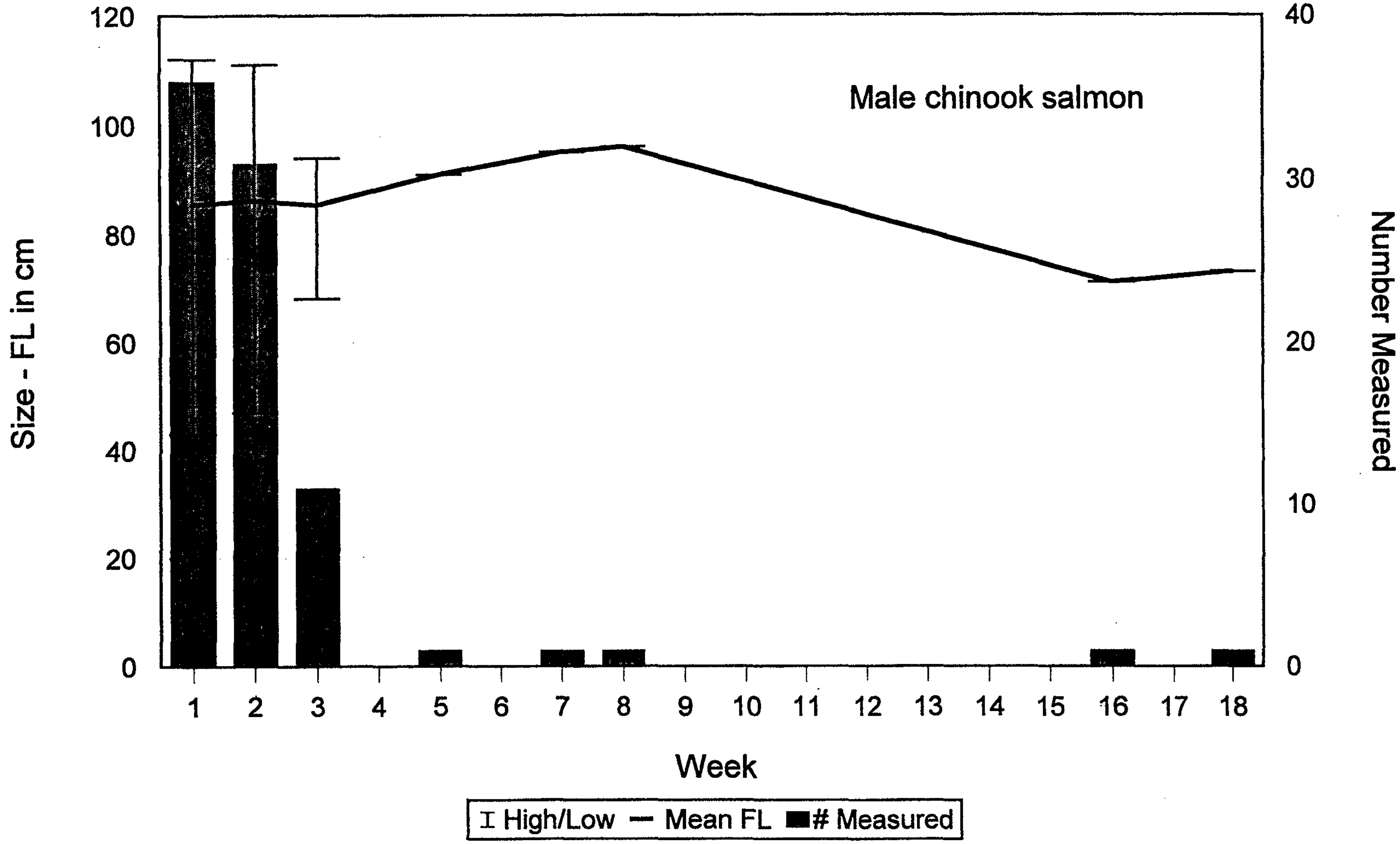

Figure 7. Mean size, size range, and number of male chinook salmon measured weekly during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

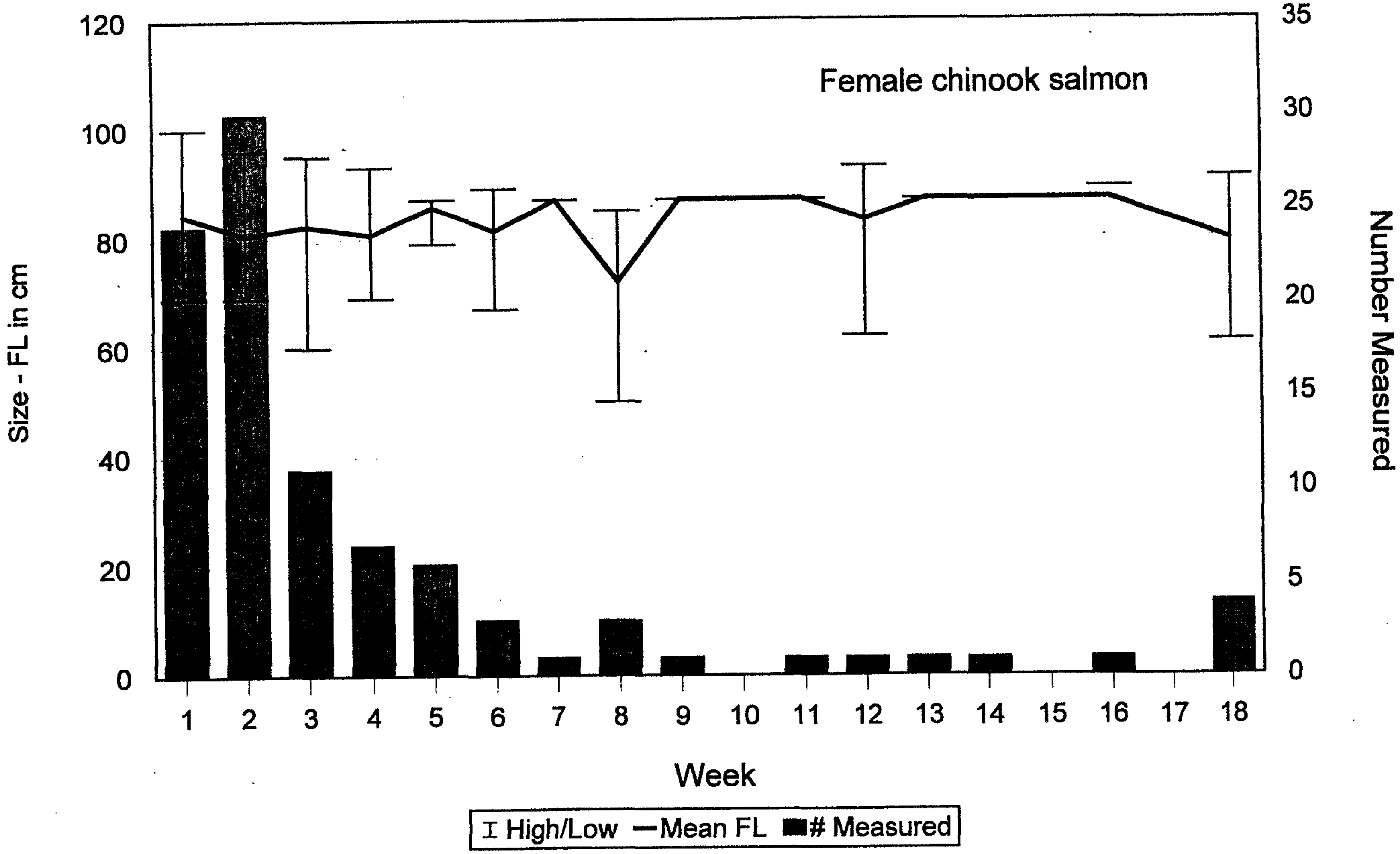

Figure 8. Mean size, size range, and number of female chinook salmon measured weekly during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

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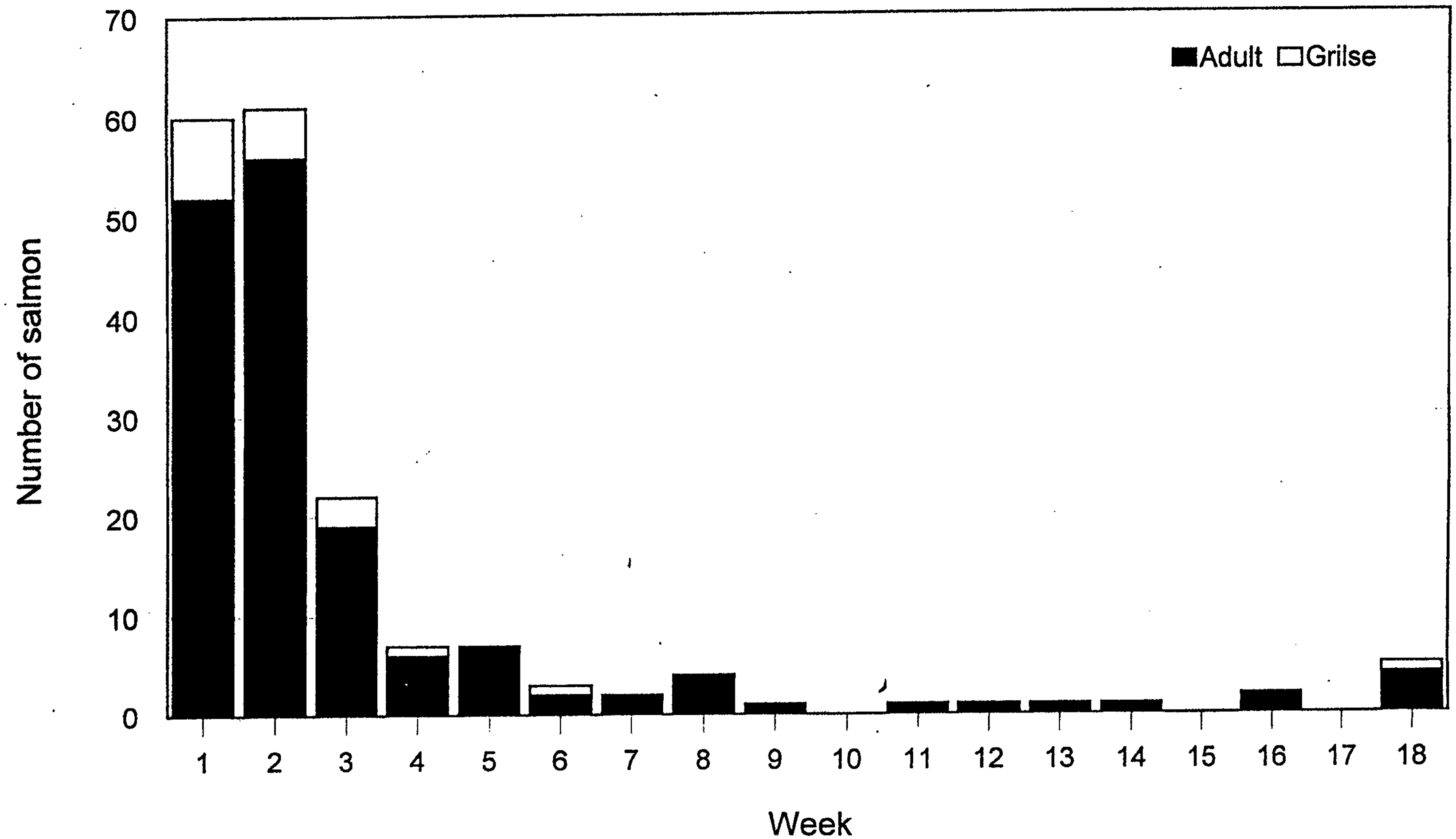

Figure 9. Age compostion of chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

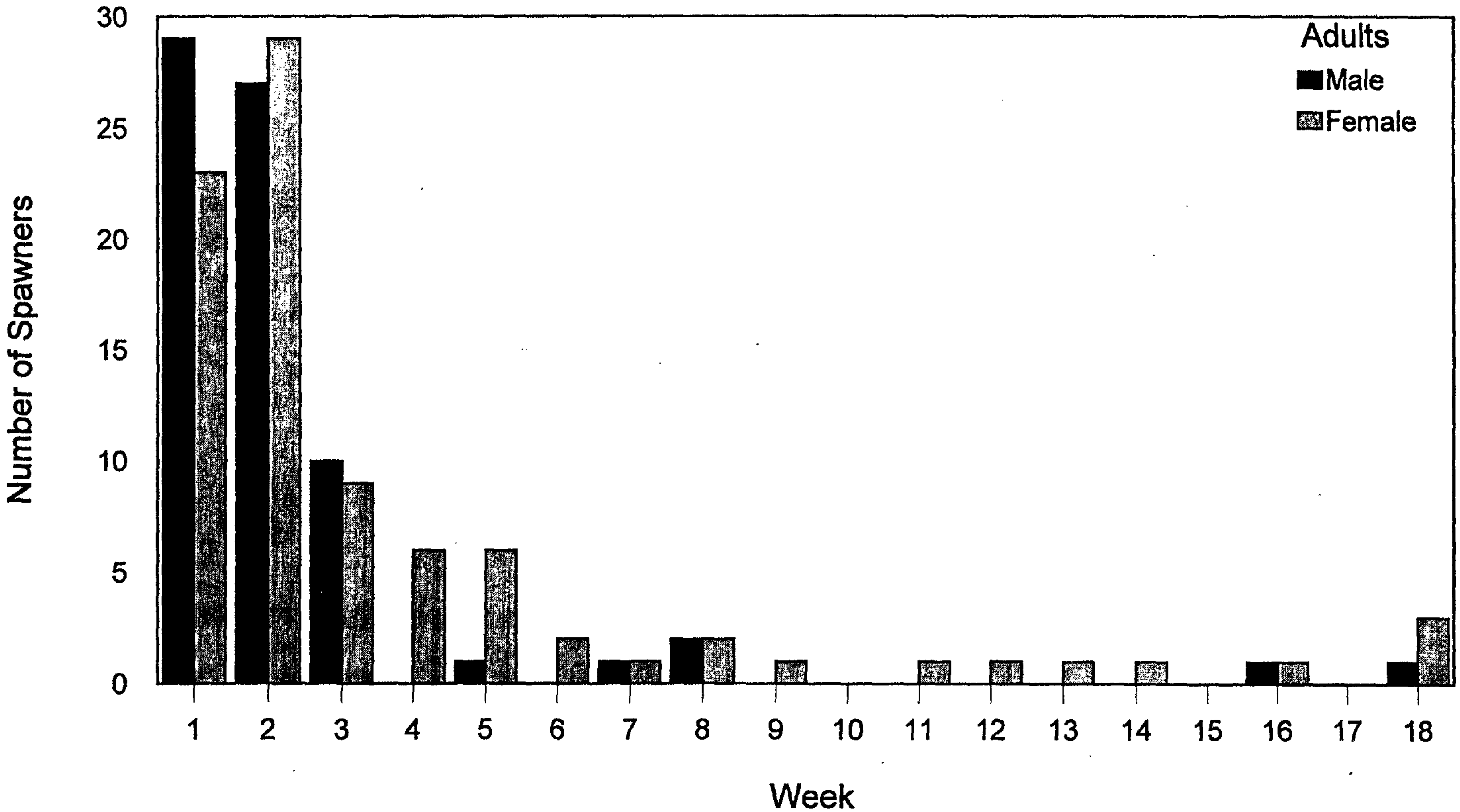

Figure 10. Weekly distribution of the sex of adult-sized chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon escapement survey, December 1997 - May 1998.

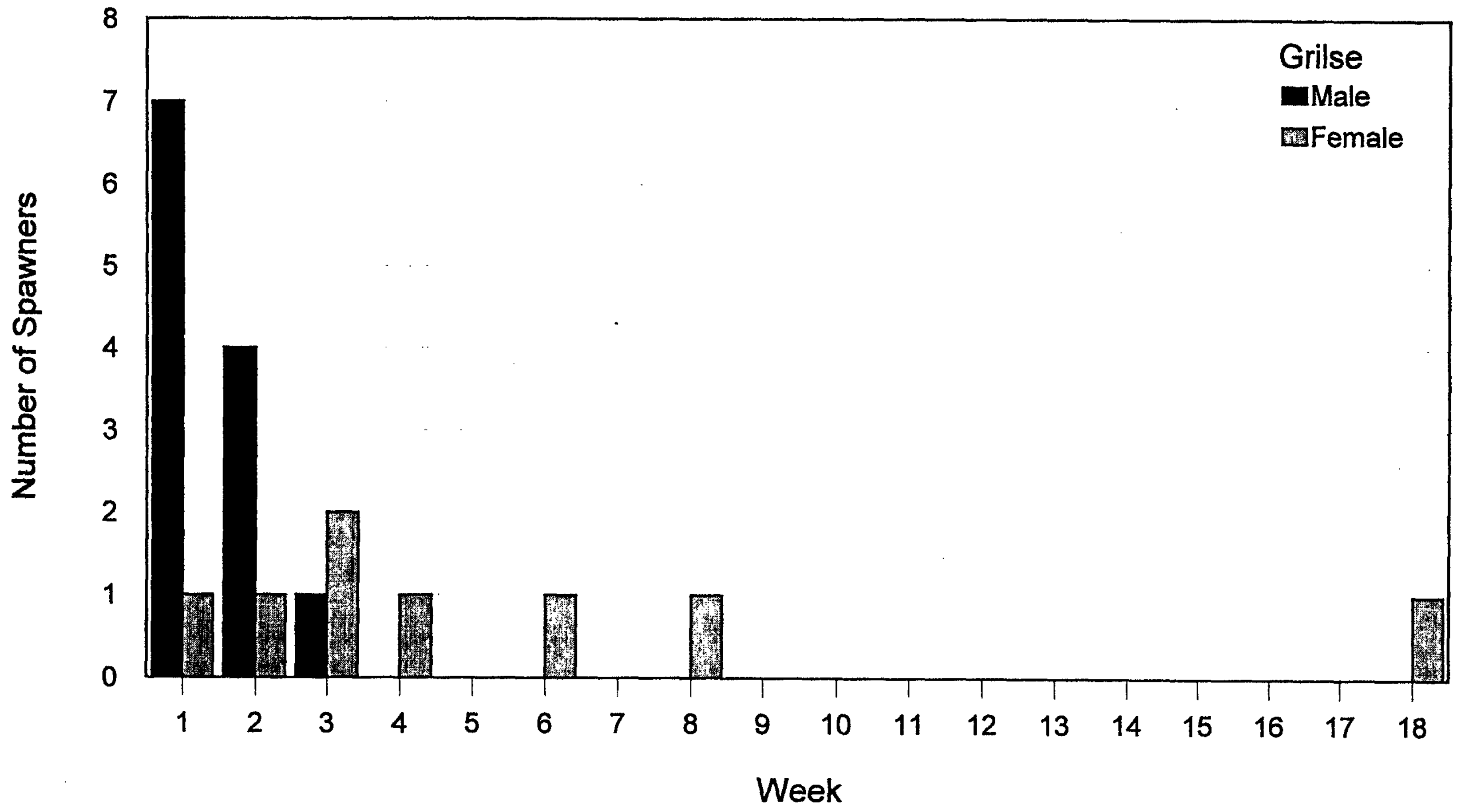

Figure 11. Weekly distribution of the sex of grilse-sized chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1997 - May 1998.

APPENDIX V

Winter-run chinook salmon spawner survey report

CALIFORNIA DEPARTMENT OF FISH AND GAME
Water and Aquatic Habitat Conservation Branch
Stream Evaluation Program

1998 Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey May - August 1998[1/]

by

Bill Snider
Bob Reavis
and
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March 1999

1/ This was a cooperative investigation with U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office. Funding was provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

SUMMARY

The California Department of Fish and Game's (DFG) Stream Evaluation Program and the US Fish and Wildlife Service's (FWS) Northern Central Valley Fish and Wildlife Office (NCVFWSO) jointly conducted a winter-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey in the upper Sacramento River during spring-summer 1998. Data were acquired on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning activity. The survey was conducted from 5 May through 28 August 1998. It covered the uppermost 14 miles of the Sacramento River accessible to migrating salmon, from river mile 288 (RM 288) upstream to Keswick Dam (RM 302). This was the third consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system.

Flow steadily increased from 10,000 cubic feet per second (cfs) at the start of the surveys (5-6 May) to 23,500 cfs on 29-30 May, then decreased to 12,600 cfs on 10-11 June. Flow then fluctuated between 14,000 and 15,200 cfs for the remainder of the survey. Water clarity (Secchi depth) ranged from 4.5 to 7.4 ft throughout May and June, and from 7.1 to 10.8 ft during the remainder of the survey. Water temperature ranged from 50° F to 54° F (mode = 52° F). Most spawning (~70%) occurred from early June into late July. Peak spawning occurred during late June, two weeks prior to the peak in fresh carcass counts.

A total 785 carcasses (382 fresh and 403 decayed) were collected. All but eight of the fresh carcasses were sexed and measured. Based upon length frequencies, 98% of the measured carcasses were adults and 2% were grilse (all males). Overall, 12% of the measured carcasses were male and 88% were female; 10% of the adults were male and 90% were female. Ninety-five percent of 327 females checked for egg retention had completely spawned. Coded-wire tags (CWT) were recovered from two fresh carcasses with adipose-fin marks. The CWT data revealed that both fish were winter-run salmon released from Coleman National Fish Hatchery: one each from the 1994 and 1995 brood years.

Spawner escapement estimates were made using a carcass mark-and-recapture method. A total of 371 fresh carcasses was tagged and 56 (15%) were subsequently recovered. Based on fresh carcass data, the Petersen model yielded an estimate of 5,391 adults. The total salmon population (adults plus grilse) was estimated by expanding the adult estimate based upon the observed proportion of fresh adult and grilse carcasses (98% and 2%). The total population estimate was to 5,501 (5,391 adult and 160 grilse). The Schaefer model was also used after being altered to account for the lack of tags being recovered from 16 of the 38 survey periods. The Schaefer escapement estimate was 4,653, (4,560 adult and 93 grilse). The effective spawner population estimates were 4,609 (Petersen) and 3,899 (Schaefer) females.

The 1998 winter-run escapement estimate based on counts made at Red Bluff Diversion Dam (RBDD) (RM 243) was 1,784 adults and 828 grilse. A discussion of the RBDD estimates and the carcass survey results is provided.

INTRODUCTION

A winter-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey was conducted in the upper Sacramento River during spring-summer 1998 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning. This was the third consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine salmon-habitat requirements in the Sacramento River system (Snider *et al.* 1998). A fundamental component of the investigation is the identification of salmon-habitat relationships at all life stages, including spawning for all salmon runs in the system. Also, since spawning habitat investigations can be influenced by both spawner abundance and habitat availability, it is important that spawner population surveys and habitat monitoring be conducted concurrently to distinguish the influences of these two factors on habitat use.

Escapement surveys conducted concurrently with redd surveys have been successfully used in the lower American River to identify relationships between spawning habitat availability and flow (Snider and McEwan 1992, Snider *et al.* 1993, Snider and Vyverberg 1995). The investigations on the lower American River strongly suggest that relationships between water temperature and temporal distribution of spawning and emergence, spawner abundance and pre-spawning mortality, flow and habitat availability, spawner abundance and habitat use as well as innate variability in expressed life history attributes can all influence the interpretation of salmon-habitat investigations. Thus, based upon our experiences in evaluating salmon-habitat relationships on the lower American River, we concluded that spawner escapement surveys should be conducted on the upper Sacramento River.

The 1996 and 1997 surveys were the first attempts to use carcass mark-and-recapture techniques to estimate winter-run chinook salmon escapement in the Sacramento River. Carcass mark-and-recapture surveys have been routinely used to estimate escapement to other Sacramento Valley tributary streams (e.g., American, Yuba, and Feather rivers and Battle Creek). This method was initially used in the Central Valley to estimate the 1973 Yuba River escapement (Taylor 1974). Three models have been used by the DFG to estimate escapement from carcass mark-and-recapture data: Petersen (Ricker 1975), Schaefer (1951), and the Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate and has been used primarily when data are insufficient to allow calculation with other models. It is occasionally used to calculate estimates for smaller salmon populations in other Central Valley tributary streams (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modified Schaefer model has been used in Central Valley tributary streams supporting "larger" salmon populations since 1973 when it was first used to estimate the Yuba River escapement. The Jolly-Seber model was first used in the Central Valley in 1988 to estimate escapement in the Feather, Yuba, American, Stanislaus, Tuolumne, and Merced rivers.

Evaluation of winter-run spawning in the Sacramento River is an integral part of an agreement between the DFG and the FWS's Central Valley Anadromous Fish Restoration Program to determine habitat requirements for anadromous salmonids in Central Valley streams. Studies being implemented by the DFG will provide the FWS with reliable scientific information for development of flow recommendations and satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B). The Sacramento River was selected for intensive fish-habitat investigations due to the significant influence the Central Valley Project has upon flow, temperature and ultimately fish habitat in the river. Furthermore, the upper Sacramento River is the only stream reach in the Central Valley that supports all four chinook salmon runs and steelhead. The exclusive occurrence of winter-run chinook salmon - a federally and state listed species - and the presence of rapidly disappearing Central Valley steelhead (listed as threatened under the federal Endangered Species Act in March 1998) underscore the significance of habitat in this stream reach.

Results of the carcass survey may be used for comparison and augmentation of data collected on winter-run migration at the Red Bluff Diversion Dam (RBDD). Similarly, the survey could augment weekly winter-run-redd surveys. The NCVFWSO and Coleman National Fish Hatchery (CNFH) could also use the results to evaluate their winter-run-escapement augmentation program using winter run spawned and reared at CNFH (USFWS 1996, Croci and Hamelberg 1997).

Objectives

The objectives of the 1998 winter-run chinook salmon spawner escapement survey were:

- To estimate the in-river, winter-run chinook salmon population in the upper Sacramento River based on a carcass mark-recapture survey and augment estimates that are based on RBDD counts.

- To continue examination of the feasibility of using mark-recapture techniques (i.e., Peterson, Jolly-Seber, and Schaefer population models) to estimate winter-run escapement in the upper Sacramento River, and recommend future escapement estimating procedures.

- To obtain baseline information on spawning distribution (spatial and temporal), environmental conditions at the time of spawning, and the spawning population (length frequency, age, sex composition, and spawning success) to eventually identify winter-run spawning habitat requirements in the upper Sacramento River.

Background

Winter run is one of four chinook salmon runs present in California's Central Valley. The other three runs are fall, late-fall, and spring. Winter run generally leave the ocean and enter fresh water to begin their upstream migration from December through June. The peak of the run normally passes RBDD in March and April. Winter run typically spawn from mid-April through mid-August.

The earliest references to winter-run salmon have been described by Fisher (1993). In 1874, Livingston Stone noted winter run in the McCloud River, a tributary to the Sacramento River that presently drains into Shasta Lake. Winter-run status since the construction of Shasta Dam has been described by Slater (1963), Hallock and Fisher (1985), and Fisher (1993). Since Shasta Dam has blocked winter run access to most of their historic spawning habitat, they now predominantly spawn immediately downstream of Keswick Dam, the upstream barrier to migration in the Sacramento River (Figure 1). Due to a drastically declining population, winter run were listed as endangered by the California Fish and Game Commission in 1989, as threatened by the National Marine Fisheries Service (NMFS) in 1990, and then as endangered in 1994.

The NMFS (1996) has developed a winter-run extinction model that identifies population conditions corresponding to an acceptable low probability of population extinction. Using the model, NMFS determined that the population will have recovered when the mean annual spawning abundance over any 13 consecutive years is at least 10,000 females. This population level assumes that the male:female ratio is 1:1 and that the age structure is comparable to that observed by Hallock and Fisher (1985) over three brood years. The assumed age structure is 50% 2-year-olds, 44% 3-year-olds, and 6% 4-year-olds for males, and 89% 3-year-olds and 11% 4-year-olds for females. The population criteria also assume that annual escapement will be estimated with a precision of $\pm$25%.

Since 1969, winter-run escapement estimates have been based upon counts of salmon using fishways that provide passage over RBDD. Counts can only be made when the diversion is in operation, (i.e., the gates are down) and all fish migrating above RBDD are forced to use the fishways located in the center and on the east and west ends of the dam. From 1969 through 1985, RBDD was typically operated throughout the entire winter-run migration period allowing a complete accounting of winter-run escapement. Unfortunately, RBDD hampers upstream migration when the gates are down and fish are migrating through the ladders. As such, beginning in 1986, the operation of RBDD was modified to improve winter-run migration. Now, the gates are typically raised from mid-September through mid-May the following year to allow most winter run unimpeded upstream passage. Since the diversion now is only operated between mid-May and mid-September, only a small portion of the winter-run migration is typically affected by the operation and thus, counted moving through the fishways.

Annual winter-run escapement is now estimated by expanding the abbreviated-season count, assuming it is proportionate to historic, entire-season counts (pre-1986). The proportion used to expand the abbreviated count is based upon the date the diversion is placed in operation and counts are initiated. The total season count is estimated by dividing the count made after the start date by the mean fraction of the total population that passed RBDD after that date when counts were season-long.

The procedures used to count salmon in the RBDD fishways include a combination of actual daytime counts (east and west fishways) and counts made from daytime video recordings (center fishway). Fish using the east and west ladders are counted directly through viewing facilities from 0600 h to 2000 h each day of the season. Fish using the center ladder are counted and identified by by reviewing video tapes made from 0600 h to 2000 h each day of the season. Once a week, the DFG determines night passage at the east and west ladders by extending the direct counts from 2000 h to 2200 h and then video taping passage from 2200 h to 0600 h the next morning to identify and count fish that had passed. The single night count is used to determine a correction factor to account for night passage for all other nights of the week. The DFG also operates a fish trap located in the east fish ladder. The trap is typically operated 7 days a week through July, then 5 days a week through mid-September, from 0600 h to 1500 h, and only when water temperatures are $\leq 60°$ F. Trapped fish are identified to species or, if a salmon, to run based upon appearance (i.e., morphological signs of sexual maturity). Fish are measured and checked for marks (e.g., adipose-fin clips).

METHODS

The NCVFWSO and the DFG's Stream Evaluation Program jointly conducted a mark-and-recapture carcass survey to estimate the number of winter-run chinook salmon spawning in the upper Sacramento River. The survey was carried out from 5 May 1998 through 28 August 1998. Methods were similar to those used during the 1997 winter-run-escapement survey (Snider *et al.* 1998).

In 1996, the survey reach extended 31 miles from Keswick Dam (RM 302) downstream to Battle Creek (RM 271) (Figure 1), which was considered the primary spawning area for winter run in the upper Sacramento River. The 1996 results, however, indicated that over 90% of winter-run spawning activity occurred in the upper 14 miles of the 31-mile survey reach. At the same time, the tag recovery rate was low (15%). As such, we decided to shorten the study reach to the 14 mile reach immediately downstream from Keswick Dam to allow increasing survey frequency in an attempt to increase recovery rates. In 1997, the study area was divided into two 7-mile reaches and each of these reaches was surveyed an average of 2.5 times per week. This change was intended to provide an adequate coverage of most of the area used by winter run to spawn and increase our tag recovery rate which in turn would provide a more accurate escapement estimate. This was continued in 1998.

The study section was divided into the following two reaches:

1. Keswick Dam to Cypress Street Bridge - RM 302 to RM 295, and

2. Cypress Street Bridge to Redding Water Treatment Plant - RM 295 to RM 288.

The upper reach was surveyed on the first day and the lower reach on the second day of each 2-day survey period. Then one day was skipped and the cycle repeated. Most of the survey effort was conducted by boat (two boats and two observers per boat). Each boat was generally used to survey along one shoreline out to the middle of the river. There were several short stretches of river that were surveyed on foot. Survey effort was intensified in areas where carcasses were known to collect. Most observed carcasses were collected using a gaff or gig, then sexed, measured and tagged, as described below.

Flow measurements from the Keswick gauge were obtained from the U.S. Geological Survey. Water temperatures and water clarity (Secchi disk) readings were measured daily by the survey crew.

Population estimates

The winter-run spawner population was estimated using a mark-and-recapture (tag-and-recovery) method. Most collected carcasses were tagged except those in an advanced state of decay. Carcasses not tagged were counted then cut in two (chopped). All chopped carcasses were disregarded in subsequent surveys. Carcasses were tagged by attaching a small colored plastic ribbon to the upper or lower jaw with a hog ring. The tag color was used to later identify the survey period that the carcass was initially tagged. Fresh carcasses (those with firm flesh and at least one clear eye) were tagged in the upper jaw. Decayed carcasses were tagged in the lower jaw. Carcass condition was noted during tagging to accommodate the various population estimators. Based on DFG protocol, results from fresh carcass data are used to calculate an escapement estimate using the Schaefer model, and results from both fresh and decayed data are used to calculate an estimate using the Jolly-Seber model. All tagged carcasses were returned to flowing water near where they were collected in an attempt to simulate "natural" carcass dispersion. Recovered, previously tagged carcasses were examined for tag color, location of tag (upper or lower jaw), and age (based on size). The pertinent data were recorded and the carcass was chopped.

The Petersen (Ricker 1975) and Schaefer (Schaefer 1951) models were used to calculate estimates from the 1998 tagging results. The Jolly-Seber (Seber 1982) was not used since it requires that there be tag recoveries from all tagging periods.

The adjusted Petersen formula (Ricker 1975) used to calculate an escapement estimate is as follows:

$$N=\frac{(M+1)(C+1)}{(R+1)}$$

Where:

N	=	Population size,
M	=	total number of carcasses tagged,
C	=	total number of examined, and
R	=	total recaptures of tagged carcasses in the *j*th recovery period.

The modified Schaefer formula (Schaefer 1951 as modified by Taylor 1974) used to calculate an escapement estimate is as follows:

$$N=\sum (R_{ij})(\frac{M_i}{R_i})(\frac{C_j}{R_j})-\sum_{i=2}^{n} M_i$$

Where:

N	=	Population size,
R_{ij}	=	number of carcasses tagged in the *i*th tagging period and recaptured in the *j*th recovery period,
M_i	=	number of carcasses tagged in the *i*th tagging period,
C_j	=	number of carcasses recovered and examined in *j*th recovery period,
R_i	=	total recaptures of carcasses tagged the *i*th tagging period, and
R_j	=	total recaptures of tagged carcasses in the *j*th recovery period.

These models were used to estimate the adult population using only data pertaining to adult-sized carcasses (e.g., number of fresh/decayed, adult-sized carcasses tagged, recovered, chopped, etc.) The total salmon population (adult plus grilse) was estimated by expanding the adult estimate in proportion to the percentage of adult-sized carcasses observed in the survey. For example, if the percentage of adult sized carcasses was 80%, the adult escapement estimate (obtained from the model) was divided by 0.80 to estimate the total population. The grilse population estimate was obtained by subtracting the adult estimate from the total estimate.

Size/age distribution and sex composition

Fork length (FL), sex, and date of collection were recorded for most measurable carcasses. (Some carcasses were too deteriorated to allow accurate measurements). The length-frequency distribution of each sex was used to define the length separating adults (>2-years old) and grilse (2-year-olds). Since results from fresh carcasses better represent the population, we only used fresh carcass data to develop length-frequency relationships and sex ratios.

Spawning success

Most measurable female carcasses were checked for egg retention. Females were classified as spent, if few eggs remained, as partially spent if a substantial amount (i.e., 50% or more) of eggs still remained in the body cavity, and unspent if they appeared to be completely unspawned.

Temporal distribution

Fresh carcasses were assumed to become available to sampling within two weeks of spawning completion, based upon observations made in the American River (Snider and Vyverberg 1995). The total number of fresh carcasses observed in both reaches during each survey period was used to describe temporal spawning distribution.

Spatial distribution

The total number of fresh carcasses observed in each survey reach was used to define season-long geographic distribution of spawning activity. Flow likely carried some carcasses from the upstream reach, where spawning occurred, to the downstream reach, where recovery occurred, potentially biasing the spatial distribution of spawning toward the downstream reach.

Hatchery-produced winter-run chinook salmon

Carcasses were also checked for adipose-fin clips, indicating the fish was of hatchery origin and possessed a coded-wire tag (CWT). Heads were collected from clipped carcasses and the CWTs were later extracted and codes read.

RESULTS

General

A total of 382 fresh and 403 decayed carcasses were observed during the 39 survey periods (Table 1). Mean flow during the 39 survey periods ranged from 10,000 to 23,500 cfs (Figure 2). Mean survey-period temperature ranged from 50° to 54° F. Secchi depth readings ranged from 4.5 to 10.8 ft and generally increased as the survey season progressed.

Population estimates

The Peterson (Ricker 1975) and Schaefer (1951 as modified by Taylor 1974) models were used to estimate escapement. The Jolly-Seber model was not used because it requires tag recoveries from each tag group released. A total of 371 fresh adult carcasses was tagged and 56 (15%) were subsequently recovered (Table 2). A total of 199 decayed carcasses was tagged and 19 (10%) were subsequently recovered.

The Peterson formula was used by combining the season-long totals for adult carcasses. Two estimates were calculated; one using only fresh carcass-recovery data, and one using all carcass-recovery data. An estimate of 5,391 adults was calculated using fresh carcass data. Assuming 98% of the populations were adults (based on length-frequency data results described later in this report), the total population estimate was 5,501 (Table 2). A second estimate of 6,349 adults was calculated using data from all tagged carcasses. This was similarly expanded to a total population estimate of 6,479. Based on Law's (1994) analysis, the estimate based on fresh carcass data is more accurate.

The Schaefer formula was not used to estimate spawner escapement in 1996 and 1997 since no tags were recovered during a substantial number of the survey periods. Similarly, in 1998, no tags were recovered during 16 of the 38 survey periods. However, due to the repetitive occurrence of this situation, we modified our application of the 1998 data to enable use of the Schaefer model. Estimates were calculated for survey periods when no tags were recovered by using fresh-carcass tagging results and assuming the recovery rates for such periods were equal to the mean of the preceding and succeeding periods when tags were recovered. For the start of the survey, the recovery rate of the fourth recovery period (the first period that tags were recovered) was used to expand the numbers observed in the first three recovery periods. For the end of the season, the numbers of carcasses observed during the 36th through 39th surveys were expanded by the recovery rate of the 35th survey period (the last period tags were recovered). The escapement estimate using this modified application of the Schaefer model was 4,560 adults. The total population estimate was 4,653.

Table 1. Summary of mean flow, mean water temperature, Secchi depths, and carcass count totals during each survey period of the upper Sacramento River winter-run chinook salmon escapement study, May - August 1998.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (° F)[2/]	Mean Secchi depth (ft)	Carcasses count[3/]	
					Fresh	Decayed
1	May 5-6	10,000	52	5.0	6	9
2	May 8-9	10,000	52	5.0	8	1
3	May 11-12	12,500	50	5.2	6	8
4	May 14-15	13,700	52	7.4	7	9
5	May 17-18	14,700	52	6.8	10	9
6	May 20-21	14,900	52	5.8	4	7
7	May 23-24	18,000	53	6.8	7	3
8	May 26-27	18,000	52	6.9	10	6
9	May 29-30	23,500	53	4.5	0	1
10	June 1-2	19,500	54	6.6	3	6
11	June 4-5	19,500	52	7.0	5	7
12	June 7-8	16,800	52	6.2	8	7
13	June 10-11	12,600	52	5.7	12	30
14	June 13-14	14,000	52	5.0	11	9
15	June 16-17,	14,700	51	5.4	13	11
16	June 19-20	15,200	52	6.6	15	17
17	June 22-23	15,000	51	6.6	17	22
18	June 25-26	14,500	52	7.4	22	14
19	June 28-29	14,400	51	7.0	26	16
20	July 1-2	14,400	52	7.2	30	32
21	July 4-5	14,900	52	8.0	24	18
22	July 7-8	15,200	52	8.2	16	14
23	July 10-11	14,900	52	7.4	17	11
24	July 13-14	14,700	52	7.7	24	22
25	July 16-17	14,800	54	8.4	13	13

Table 1 (cont.). Summary of mean flow, mean water temperature, Secchi depths, and carcass count totals during each survey period of the upper Sacramento River winter-run chinook salmon escapement study, May - August 1998.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (° F)[2/]	Mean Secchi depth (ft)	Carcasses count[3/]	
					Fresh	Decayed
26	July 19-20	14,800	54	8.2	10	10
27	July 22-23	14,700	52	7.1	11	12
28	July 25-26	14,600[4/]	52	7.2	4	6
29	July 28-29	14,800	52	8.4	6	22
30	July 31-Aug 1	15,000	52	8.4	7	8
31	August 3-4	15,000	53	7.8	13	10
32	August 6-7	14,600	52	9.4	6	14
33	August 9-10	14,700	52	9.0	4	2
34	August 12-13	14,700	54	9.2	1	2
35	August 15-16	14,600	54	8.8	3	5
36	August 18-19	14,900	52	9.2	1	5
37	August 21-22	14,800	52	8.8	1	1
38	August 24-25	14,600	52	10.8	1	3
39	August 27-28	14,300	52	10.6	0	1
				Totals -	382	403

1/ Mean flow at Keswick Dam during survey period as measure by U.S. Geological Survey.
2/ Mean water temperature measured each day by survey crew.
3/ Includes grilse and adults; does not include tag recoveries.
4/ No flow measurement recorded for 25 July 1998.

Table 2. Summary for each tagging period of number observed (fresh and decayed), tagged (fresh), and recaptured (fresh) during 1998 upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
1	May 5-6	15	0	6	0	0
2	May 8-9	9	0	8	0	0
3	May 11-12	14	0	5	0	0
4	May 14-15	15	1	7	0	0
5	May 17-18	19	0	10	0	1(4)
6	May 20-21	11	0	4	0	2(5),1(4)
7	May 23-24	9	1	6	1	0
8	May 26-27	16	0	9	0	2(7),1(6),
9	May 30-31	1	0	0	0	0
10	June 1-2	9	0	2	0	0
11	June 4-5	12	0	5	0	0
12	June 7-8	15	0	8	0	0
13	June 10-11	40	2	11	1	0
14	June 13-14	20	0	11	0	1(13)
15	June 16-17	24	0	13	0	2(14)
16	June 19-20	31	1	14	1	0
17	June 22-23	38	1	17	1	1(15),1(13)
18	June 25-26	36	0	22	0	5(17)
19	June 28-29	42	0	26	0	1(18)
20	July 1-2	60	1	30	0	1(19),1(18)
21	July 4-5	42	0	24	0	3(20),1(19)
22	July 7-8	30	0	16	0	2(21),1(19)
23	July 10-11	26	2	16	1	5(22),2(21)
24	July 13-14	43	3	23	1	1(23),3(22),2(21)
25	July 16-17	26	0	13	0	3(24),1(23),1(21)

Table 2 (cont.). Summary for each tagging period of number observed (fresh and decayed), tagged (fresh), and recaptured (fresh) during 1998 upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
26	July 19-20	20	0	9	1	0
27	July 22-23	22	1	11	0	1(26)
28	July 25-26	10	0	4	0	0
29	July 28-29	27	2	6	1	1(28)
30	July 31 - August 1	15	0	7	0	1(26)
31	August 3-4	23	0	13	0	1(30),1(29),1(28),1(26)
32	August 6-7	20	0	6	0	1(31),1(30)
33	August 9-10	6	0	4	0	2(32),1(29)
34	August 12-13	3	0	1	0	1(32),1(31)
35	August 15-16	8	0	1	0	1(34)
36	August 18-19	5	1	1	0	0
37	August 21-22	2	0	1	0	0
38	August 24-25	4	0	0	0	0
39	August 27-28	1	0	0	0	0
	Totals	769	14	371	5	56

* All were adults, no grilse were recovered.

Size/age distribution and sex composition

A total of 374 carcasses was measured (Table 3). Mean FL was 68.8 cm (range: 45-102 cm FL). Male salmon (n = 44) averaged 73.7 cm FL (range: 45-92 cm FL). Female salmon (n = 330) averaged 68.1 cm FL (range: 55-102 cm FL). The largest fish were observed during the first month. The mean size of males narrowly ranged from 74.7 to 76.0 cm FL during May, June, and August (Figure 3). The mean size of males was smaller during July (62.7 cm FL) when three of the seven measured males were grilse. The mean monthly size of females was the greatest during May (71.2 cm FL), and narrowly ranged from 67.5 to 67.9 cm FL for the remainder of the survey.

The female and male length frequency distributions were quite different (Figure 4). About 98% of the females were grouped in a normal distribution that ranged from 55 to 79 cm FL with a mode of 66 cm FL. These fish were likely all 3-years old. The remaining 2% of the female population ranged from 84 to 102 cm FL and were likely 4-years old. The male distribution was discontinuous exhibiting a relatively large gap between 57 cm FL and 63 cm FL (Figure 4). We used these data to define 60 cm FL as the size criterion separating male grilse (2-year-old salmon) and male adults (>2-year-old salmon). We plan to verify the age/length relationship for the 1998 spawner population using scales and otoliths taken from most measured carcasses.

Male grilse averaged 51.6 cm FL (SD = 4.3; range: 45-57 cm FL) (Table 4). Male adults averaged 77.9 cm FL (SD = 6.8; range: 63-92 cm FL). Female adults averaged 68.1 cm FL (SD = 6.1; range 55-102 cm FL). As previously stated, no female grilse were observed.

Ninety-eight percent (n = 367) of the fresh carcasses measured were adults and 2% (n = 7) were grilse (Table 5). At least 96% of the carcasses observed each month were adults.

All grilse were males which made up only 2% of the total population and 16% of the male population (Table 6). The adult sample comprised 90% (n = 330) females and 10% (n = 37) males. The ratio of male to female adult spawners was 1 to 8.9. The overall sex ratio, including grilse, was 1to 7.5.

Spawning success

Ninety-five percent (n = 310) of the 327 fresh female carcasses examined for egg retention had completely spawned. Two percent (n = 7) had partially spawned, and 3% (n = 10) had not spawned. Unspawned and partially spawned females were observed throughout the survey.

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Table 3. Size and sex statistics for winter-run chinook salmon carcasses measured during upper Sacramento River escapement survey, May - August 1998.

	All salmon			Male salmon			Female salmon		
		Length (FL in cm)			Length (FL in cm)			Length (FL in cm)	
Month	Number measured	Mean	Range	Number measured	Mean	Range	Number measured	Mean	Range
May	57	72.7	51-102	17	76.0	51-87	40	71.2	59-102
June	127	68.9	45-97	18	74.7	45-92	109	67.9	56-97
July	162	67.4	47-86	7	62.7	47-81	155	67.5	55-86
August	28	68.2	57-102	2	76.0	71-81	26	67.6	57-102
Total (mean)	374	68.8	45-102	44	73.7	45-92	330	68.1	55-102

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Table 4. Summary of adult and grilse size and number by sex for winter-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, May - August 1998.

	Female		Male	
	Grilse	Adults	Grilse*	Adults
Total measured	0	330	7	37
Mean	-	68.1	51.6	77.9
Range FL (cm)	-	55-102	45-57	63-92
SD	-	6.1	4.3	6.8

* Grilse were defined as male salmon ≤ 60 cm FL.

Table 5. Age composition (grilse and adult) of winter-run chinook salmon carcasses measured during the upper Sacramento River spawner escapement survey, May - August 1998.

Month	Adults		Grilse	
	Number	%	Number	%
May	55	96	2	4
June	125	98	2	2
July	159	98	3	2
August	28	100	0	0
Totals (mean)	367	(98)	7	(2)

Table 6. Sex composition of winter-run chinook adult and grilse carcasses measured during the upper Sacramento River escapement survey, May - August 1998.

	Adults				Grilse			
	Male		Female		Male		Female	
Month	Number	%	Number	%	Number	%	Number	%
May	15	27	40	77	2	100	0	0
June	16	13	109	87	2	100	0	0
July	4	3	155	97	3	100	0	0
August	2	7	26	93	0	-	0	-
Totals (mean)	37	(10)	330	(90)	7	(100)	0	(0)

Table 7. Summary of salmon carcass distribution observed during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998. Summary includes fresh and decayed, adults and grilse carcasses but not tag recoveries.

	Reach 1		Reach 2	
Survey period	Fresh	Decayed	Fresh	Decayed
1	2	4	4	5
2	5	1	3	0
3	2	3	4	5
4	5	2	2	7
5	2	2	8	7
6	0	3	4	4
7	3	1	4	2
8	4	2	6	4
9	0	0	0	1
10	0	1	3	5
11	2	7	3	0
12	3	1	5	6
13	4	15	8	15
14	3	5	8	4
15	2	8	11	3
16	11	6	4	11
17	12	9	5	13
18	12	8	10	6
19	10	7	16	9
20	24	21	6	11
21	14	15	10	3
22	8	11	8	3
23	11	2	6	9
24	16	12	8	10
25	11	6	2	7
26	6	6	4	4
27	9	6	2	6
28	2	5	2	1
29	6	20	0	2
30	6	7	1	1
31	11	8	2	2
32	5	11	1	3
33	3	0	1	2
34	1	2	0	0
35	3	4	0	1
36	1	5	0	0
37	1	1	0	0
38	1	2	0	1
39	0	1	0	0
Totals	221	230	161	173

Spatial distribution

The majority of both fresh and decayed carcasses were observed in the upper reach. Fifty-eight percent (n = 221) of the fresh carcasses and 57% of decayed carcasses (57.4% total) were (Table 7) observed in Reach 1. The ratios of fresh to decayed carcasses were 1:1 in Reach 1 and 1:1 in Reach 2.

Temporal distribution

Fresh carcasses were observed from survey period 1 (5-6 May 1998) through survey period 38 (24-25 August 1998) (Table 1, Figure 5). The number of fresh carcasses observed during May fluctuated from zero (29-30 May 1998) to 10 (17-18 and 26-27 May 1998). The fresh carcass numbers gradually increased in June and peaked at 30 carcasses during the 1-2 July 1998 survey period. Fresh carcass numbers generally declined during the remainder of the study. About 66% of fresh carcasses were observed between 10 June 1998 and 23 July 1998.

Winter-run spawning occurred from late-April 1998 into mid-August 1998, assuming that fresh carcasses are available for observation approximately two weeks after spawning (Snider and Vyverberg 1995). Over 80% of spawning occurred from mid June 1998 through late July 1998; peak spawning occurred during early July (Figure 5).

Hatchery-produced winter-run chinook salmon

Four adipose-clipped carcasses (2 fresh and 2 decayed) were collected (Table 8). CWTs were only recovered from the two fresh carcasses. Data from the two CWTs revealed that the two salmon were winter-run chinook salmon produced at CNFH. One CWT was recovered on 14 June 1998 (Tag # 05-01-01-10-06) from an 84 cm FL, 4-year old (1994 brood year) male. The other CWT was recovered on 9 August 1998 (Tag # 05-01-01-14-15) from a 61 cm FL, 3-year old (1995 brood year) female.

Table 8. Summary of adipose-clipped (hatchery-produced) carcasses collected during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

Date collected	Tag number	Sex	FL (cm)	Brood year
June 13	no tag[1/]	Female	63	?
June 14	05-01-01-10-06	Male	84	1994
June 29	no tag[1/]	Female	65	?
August 9	05-01-01-14-15	Female	61	1995

1/ No tags were recovered from the decayed carcasses. The CWT may have been lost due to the carcasses decayed state, or the adipose clip may have been false, caused by the decay.

DISCUSSION

The results of three years of carcass surveys cannot by themselves address the issues of habitat availability relative to flow and other attributes of physical habitat. Several more years of survey are needed. These data should then be compared with redd survey data to identify salmon spawning habitat requirements. The low population level may also reduce the efficacy of the population surveys in evaluating habitat needs. If the population is so low relative to habitat availability, little can be determined with these data alone, especially relative to the habitat conditions necessary to support the targeted, recovery population of at least 20,000 fish (NMFS 1996). However, if habitat is limiting at these low populations, habitat-flow relationships should be identifiable. Other studies that will augment this component of the overall investigation may include aerial photographic surveys of redds, physical habitat modeling, and focused evaluation of the hydraulic and substrate attributes of spawning habitat.

Population estimates

Law (1994) found that the Petersen model consistently showed substantially larger overestimation than either the Schaefer or Jolly-Seber models. When both fresh and decayed carcasses are used, he found that the Petersen model overestimated the known population by as much as 151%, and by as much as 84% when only fresh carcasses were used. He assumed a catch (recovery) rate of 40%, a tagging rate of 90%, and survival or carry over rates for each consecutive recovery period of 80%, 40%, 20%, and 0%. We used both fresh and decayed carcasses to derive the estimate of 6,479 winter run. Using just fresh carcasses, the estimate is 5,501. Law found that the Schaefer model also overestimated the known population by 78% when both fresh and decayed carcasses are used, and by 52% when only fresh carcasses are used. The altered Schaefer model using fresh carcass data provided an estimate of 4,653. All three estimates likely overestimate the true population.

The most appropriate winter-run escapement estimate to provide population trends is the one derived from the Petersen formula using fresh carcass data. Although this model will likely overestimate the true population, data will likely be available every year to permit calculation of a population estimate, unlike the Schaefer and Jolly-Seber models. Unless winter-run population is maintained at greater numbers, there will not be enough tag recoveries to allow use of the Jolly-Seber or Schaefer models in most years even though these models would provide a more accurate estimate.

One of the goals for the 1998 survey was to improve upon the recovery rate observed during the earlier two surveys (12% in 1997 and 15% in 1996). The overall 1998 tag recovery rate, however, was still only 13%. Probable reasons for low tag recoveries include poor visibility and high flows. Reduced visibility during part of May combined with flows that increased from 10,000 cfs on 5-6 May to 23,500 cfs on 29-30 May hampered early carcass recovery efforts. Tag recoveries were low until 10 June and then showed an increase concurrent with improved water clarity and declining flows (Figure 6).

In contrast, recovery rates for upper Sacramento River fall-run chinook salmon during the 1995 through 1997 escapement surveys ranged from 26% to 33%. Flows during the fall-run survey periods are typically around 5,000 cfs, which are much less than during the winter-run surveys (Snider et. al. 1997).

Effective spawner population

The effective spawner population is defined as the estimated number of females that spawned, assuming there were enough males to service all the redds. Since 90% of the carcasses used to estimate adult escapement were female, the estimated female population based on the carcass survey was 4,852 (based on Petersen formula using fresh carcass data). Prespawning mortality was 5% yielding an estimated effective spawner population of 4,609.

Sex composition

The ratio of males to females observed during the carcass surveys was 1:7.5 compared to 1:3 during 1997 and 1:6.4 during 1996. The sex ratio varied throughout the survey ranging from 1:2.4 in May (n = 57), 1:6.1 in June (n = 127), 1:22.1 in July (n = 162) and 1:13.0 in August (n = 28).

The following are possible explanations for the observed difference in sex composition:

1. The recovery rate of males is less than for females. In a carcass survey and weir count conducted on Bogus Creek, a tributary to the Klamath River, the recovery rate of adult males was 11% less the rate for females (Boydstun 1994).

2. If a high portion of the male population leaves the ocean as 2-year-olds, the male to female ratio of that age class remaining in the ocean is reduced significantly. Based on the age composition criteria used in the NMFS model, 50% of the returning males would be grilse. Assuming an initial sex ratio of 1:1, this alone would result in a male to female ratio of nearly 1 to 2. As the proportion of males returning as 2-year-olds increases (x), the ratio of male to female adults for that age class decreases to 1:(1/1-x) (e.g., if x = 0.5, the ratio is 1:2; if x = 0.7, the ratio is 1:3.3, *etc.*).

3. A combination of the above two factors would produce an even greater disparity between adult males and females.

Comparison with Red Bluff Diversion Dam winter-run escapement estimates

Results of the salmon counts at RBDD indicated an estimated 2,612 in-river produced winter run, including 1,784 adult and 828 grilse, migrated to the upper Sacramento River (DFG unpubl. data). RBDD data also indicate that an estimated 15 hatchery-produced winter run migrated to the upper Sacramento River. The male to female ratio for adults was not reported.

Adult escapement estimated from the carcass survey data was 2.5 to 3 fold greater than the RBDD estimate. The disparity may be explained by the fact that both the Petersen and Schaefer models typically overestimate escapement when applied to carcass survey data. However, it is unlikely that we would observe 769 adult salmon, nearly 45% of the total number of adults estimated to pass RBDD, especially since some winter run spawn downstream of the survey reach and some likely died before spawning. Also, it is unlikely that collecting, marking then returning the carcasses to the river would bias recovery to the extent that we observe carcasses from nearly one of every two winter run that spawn in the river, but can recover less than one of every six salmon that we mark. For the two methods to produce equivalent estimates, we would have needed to recover over 40% of the marked carcasses, an extremely high recovery rate. As such, it is likely that not only does the carcass survey over estimate the population, but that the RBDD estimate is low.

Another possible explanation for the disparity is that the percentage of fish moving past RBDD during the counting period was less than the estimated 13.4% (assuming the RBDD estimate is low). To evaluate the estimated proportion of the run that passed RBDD during the counting period, we conducted a sensitivity analysis using estimates of adipose-clipped winter run made at RBDD and subsequently in the upper river system (Snider et al. 1998). The estimated number of adipose-clipped winter run returning to the upper drainage was 113. One hundred hatchery-produced winter run were estimated to return to Battle Creek (S. .Hamelberg, FWS, unpubl. data), and 13 hatchery-produced winter run were estimated to have spawned in the Sacramento River survey area (carcass survey results). The escapement of hatchery-produced winter run based on RBDD counts (15) was less than 15% of the upper basin estimate. The RBDD estimate was based on the expansion of a count of 2 adipose-clipped fish and the assumption that the counting period accounted for 13.4% of the total migration. If we assume that the actual number of hatchery-produced winter run migrating past RBDD was at least 113, as described above, then the proportion of the run counted at RBDD was no more than 2/113, or 1.7%, compared to 13.4%. Note that the proportion of fish moving past RBDD after 15 May (measured between 1969 and 1985) is quite variable and the proportion of 1.7% lies within the observed range (Figure 7). Assuming that 1.7% of the in-river produced (non-clipped) winter run also passed RBDD during the counting period, (i.e., 350 salmon represents 1.7% of the winter-run population passing RBDD), the estimated number of in-river produced winter run passing RBDD becomes 20,588 (350/.017), comprising 14,062 adult and 6,526 grilse.

Results of this analysis suggest that there are some major errors in either the assumptions (i.e., that the migration timing of in-river and hatchery produced winter run is comparable as used in the RBDD estimate and in our sensitivity analysis), or in the estimates of adipose-clipped salmon, or both. The errors may simply be due to a very small number of adipose-clipped fish returning to the system that in turn amplifies any differences between the two estimates.

Estimates of adipose-clipped winter run entering Battle Creek in 1998 were not based upon video counts, as in the past, due to high flows preventing such counts. As such, the estimate in Battle Creek was less accurate, but details of the estimate are unavailable for further discussion. The estimated number of adipose-clipped fish entering the carcass survey area was likely high. However, the number was so low that even assuming that all adipose-clipped fish using the area were observed (i.e., only two clipped salmon entered the area) the influence on the sensitivity analysis, above, is negligible. Conversely, a small change in the count at RBDD can substantially change the adipose-clipped winter-run estimate and subsequent analysis. For example, if two more clipped fish were observed at RBDD, the estimate doubles, at least, decreasing the estimated percentage of the run passing RBDD in our sensitivity analysis from 1.7% to 3.5%, which decreases the estimated adult population to 6,830. As such, it should be noted that 3% (two of the 65) winter run captured in the RBDD trap were adipose clipped, but the estimated proportion of adipose-clipped fish passing RBDD was less than 0.6% (15 out of 2,627). The difference is due to the expansion of fish counted, by video and by direct observation. No adipose-clipped fish were counted beyond those in the trap. The potential for missing a clipped fish likely exists which could substantially change the clipped salmon estimate. Regardless of the reasons, the data used to conduct a sensitivity analysis of the 1998 winter-run escapement estimates are deficient, and the analysis results do not reduce the uncertainty as to the accuracy of the estimates.

The disparity in estimates of adult winter-run escapement is even further exaggerated when comparing effective spawner population estimates. The effective spawner population estimated using the RBDD data (assuming a 1:1, female:male ratio and 5% prespawning mortality) is 1,202. The effective spawner population estimated using the Petersen model results is 4,449 and 3,707 using the Schaefer model estimate. Since some portion of the population migrating past RBDD dies, or otherwise does not reach the spawning survey area, the RBDD estimate should exceed the number of fish expected to spawn in the survey area. However, the carcass survey estimates are three to nearly four times the RBDD estimate.

One distinct difference between the carcass survey and RBDD count that influences the estimate of the effective spawner population is the criteria used for distinguishing adult and grilse. At RBDD, grilse are defined as salmon < 65 cm FL. The length frequency analysis used to differentiate grilse and adult in the carcass survey suggests that a substantial portion (24%) of the female adult population was < 65 cm FL. (The discrepancy could also account for the relatively high proportion of grilse in the RBDD [31.7%] versus only 2% in the carcass survey). If we adjust the RBDD population data to reflect the carcass survey findings, (i.e., 1,202 females represents 76% of the adult female population), the RBDD effective spawner estimate increases to 1,581 females. The differences between the two estimates are substantial.

RECOMMENDATIONS

1. The mark and recapture carcass surveys should be continued to compliment RBDD counts and potentially improve application of the results in identifying escapement numbers and eventually winter-run habitat relationships in the upper Sacramento River.

2. Investigate the discrepancies between the sex ratios observed during the carcass survey and the fish trapped at RBDD.

3. One of the principal questions that needs to be addressed is whether there is a difference in the availability of male and female carcasses to our sampling procedures. One possible explanation for the low male to female ratio observed in 1996 and 1997 is due to post- spawning behavior differences. Males may move downstream or to areas unavailable to sampling (e.g., deep pools), while females stay on the redd until they die and therefore are more susceptible to sampling. An effort should be made to determine if the ratio of male to female carcasses in deep (pool) areas is different from that observed in our surveys. This could be done several times throughout the spawning season using video surveillance or diving.

3. The length at age criteria used to identify the age of female and male winter run should be verified using scales and otoliths collected from the sampled carcasses.

4. The methods used to estimate adipose-clipped fish passing RBDD and in the upper river system need to be addressed relative to the utility of the appropriateness of the sensitivity analysis discussed herein as a tool for adjusting RBDD and carcass survey results.

5. The RBDD count data collected from 1969 through 1998 should be further evaluated to determine the validity of using a four-year mean to describe the proportion of winter run passing RBDD once the gates are closed.

6. The 1996 through 1998 carcass survey data should be combined with RBDD and other appropriate data to address the best way to combine information to reduce uncertainty surrounding estimating winter-run escapement.

7. Comparison of winter-run juvenile emigration data with escapement data should be evaluated as another means of reducing uncertainty of escapement estimates.

ACKNOWLEDGMENTS

Survey data were gathered by: Vina Free, Jeffery Jahn, Jason Kindopp, Kirshnan Nelson, Randy Rickert, Chris Wilkinson, and Julie Zerr with the FWS; Chris Cox, John Galos, Mike Hendrick, James Lyons, Jordan McKay, Brian Sardella, Mike Spiker, Jada Simone-White with the DFG. Data were processed and summarized by Katherine Taylor of DFG. We thank those individuals for their efforts, as well as Frank Fisher for providing logistical and technical support and Jim Smith (FWS) for facilitating a cooperative investigation.

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FIGURES

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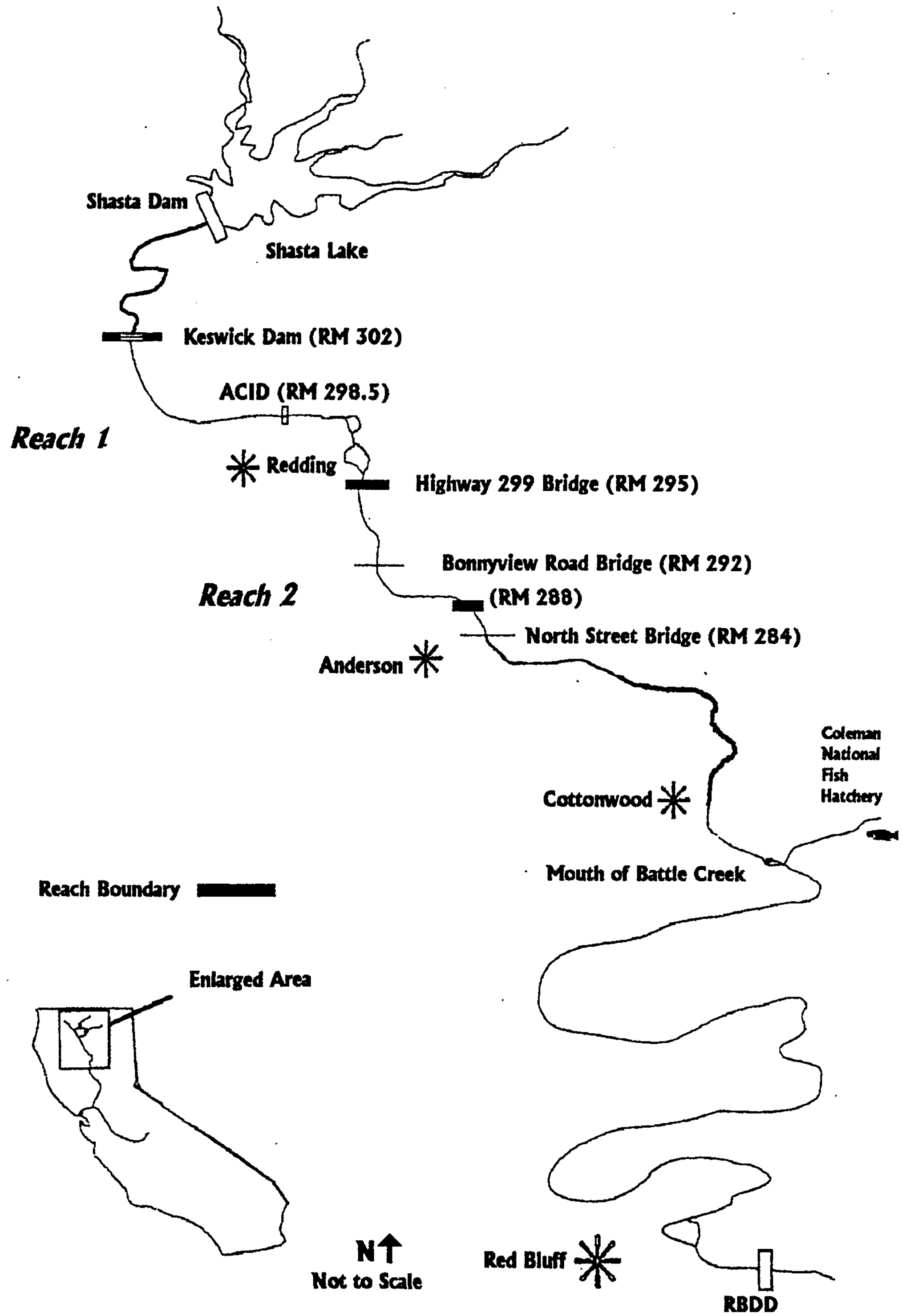

Figure 1. Upper Sacramento River winter-run chinook salmon escapement study location including reach designations, May - August 1998.

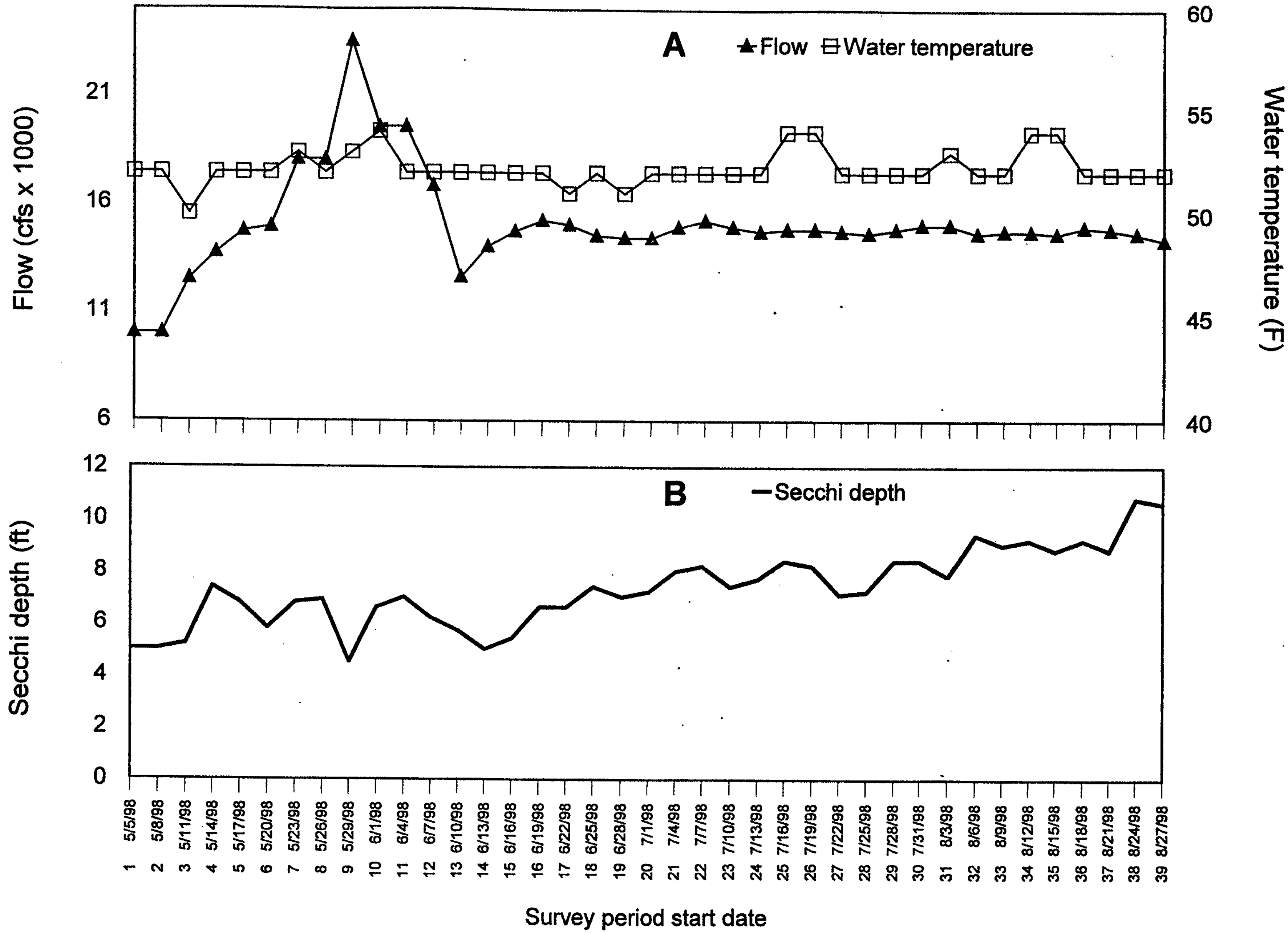

Figure 2. Mean flow and water temperature (A) and Secchi depth (B) measured for each survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

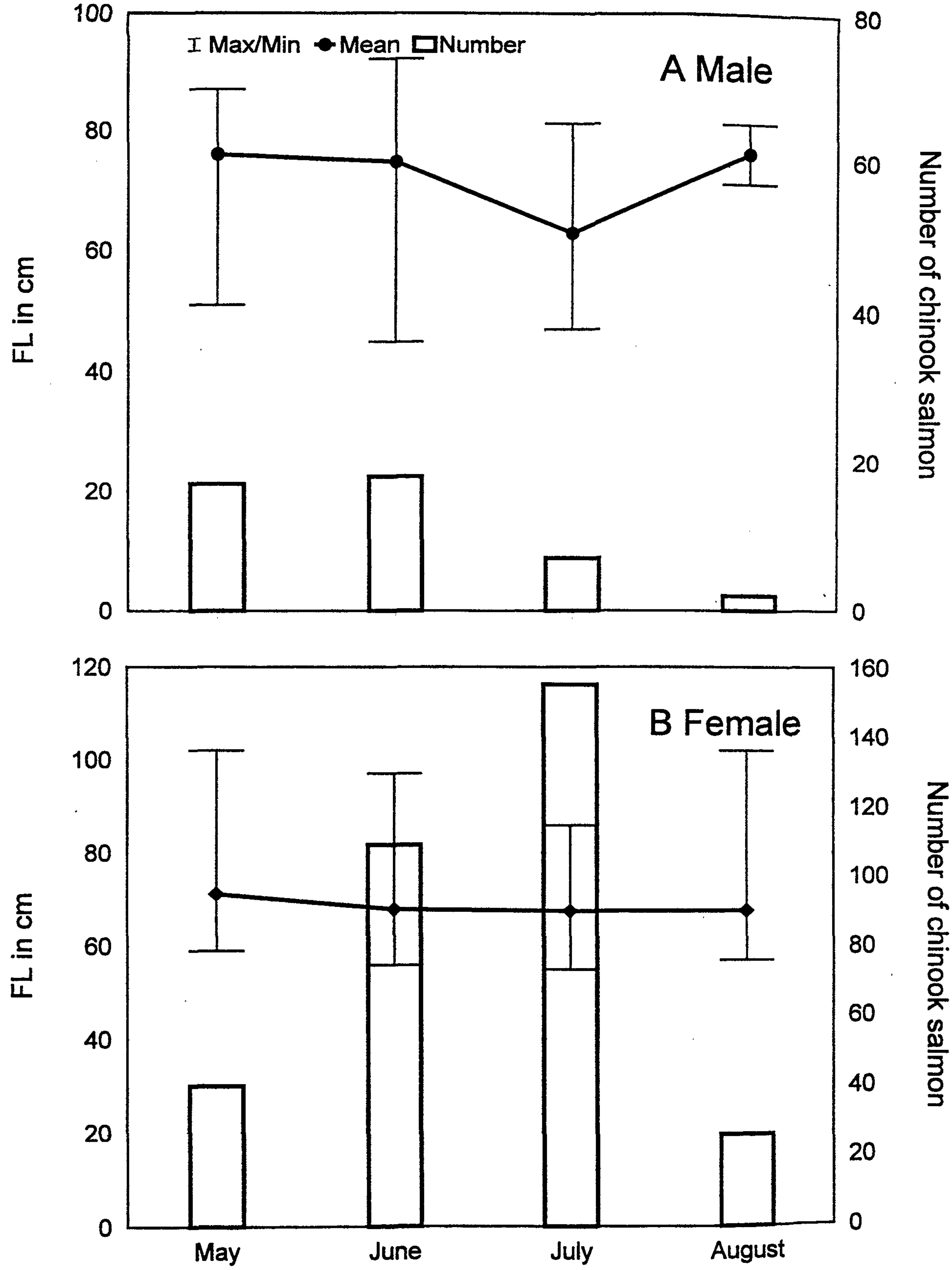

Figure 3. Catch and size distribution of (A) male and (B) female chinook salmon collected during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

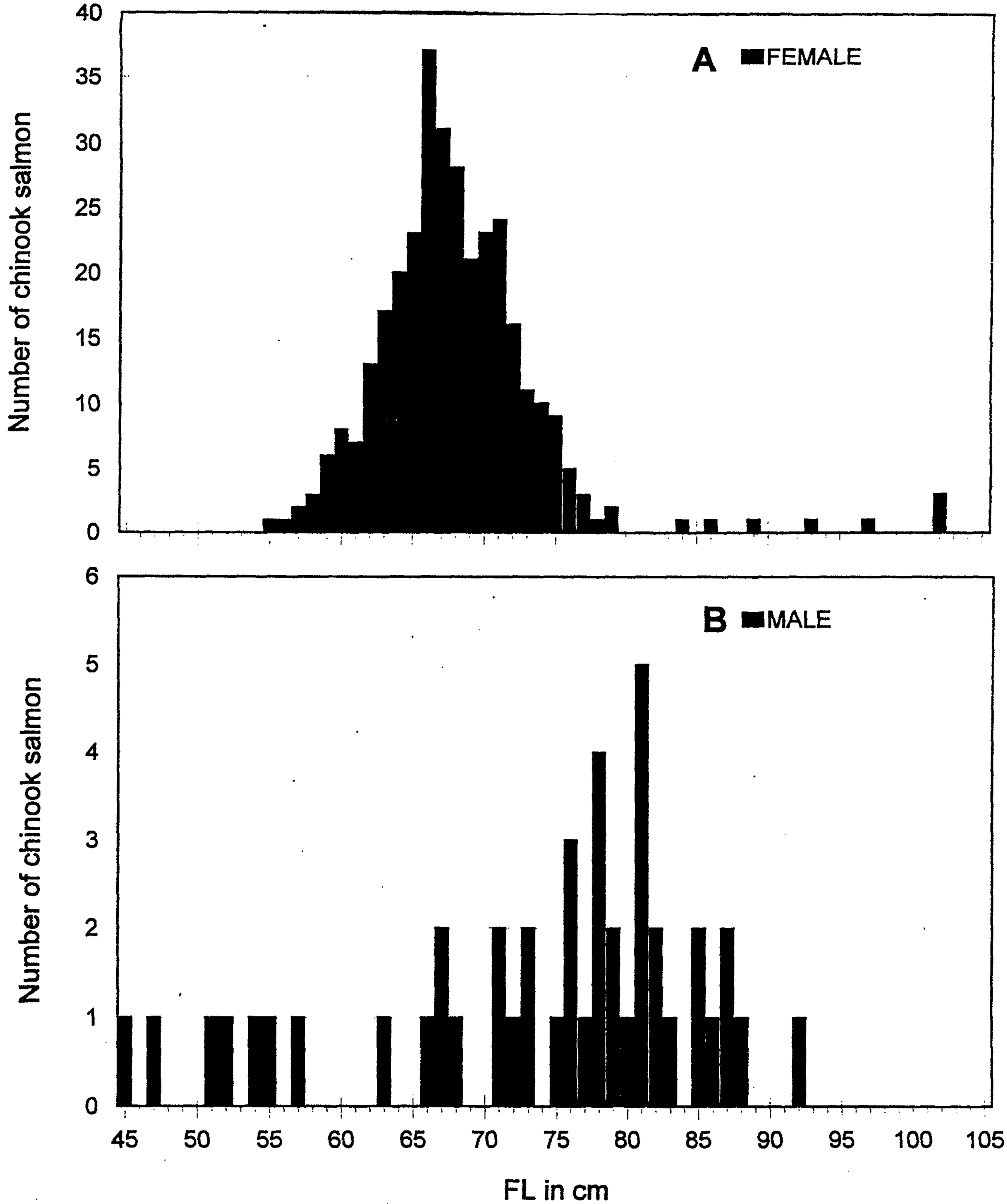

Figure 4. Length-frequency distributions for (A) female and (B) male salmon measured during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

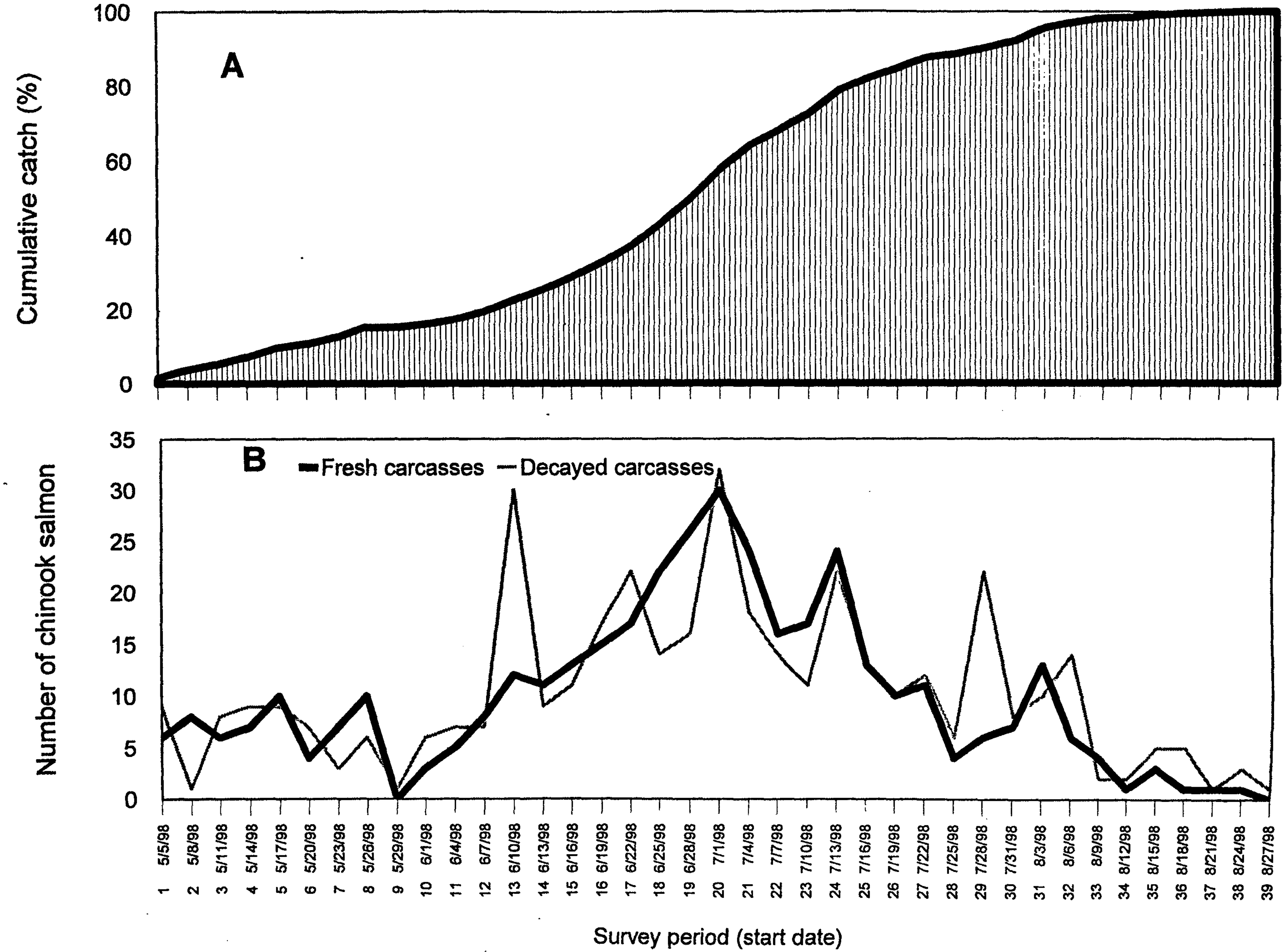

Figure 5. Cumulative catch of fresh carcasses (A), and catch distribution of fresh and decayed carcasses (B) , by survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May-August 1998.

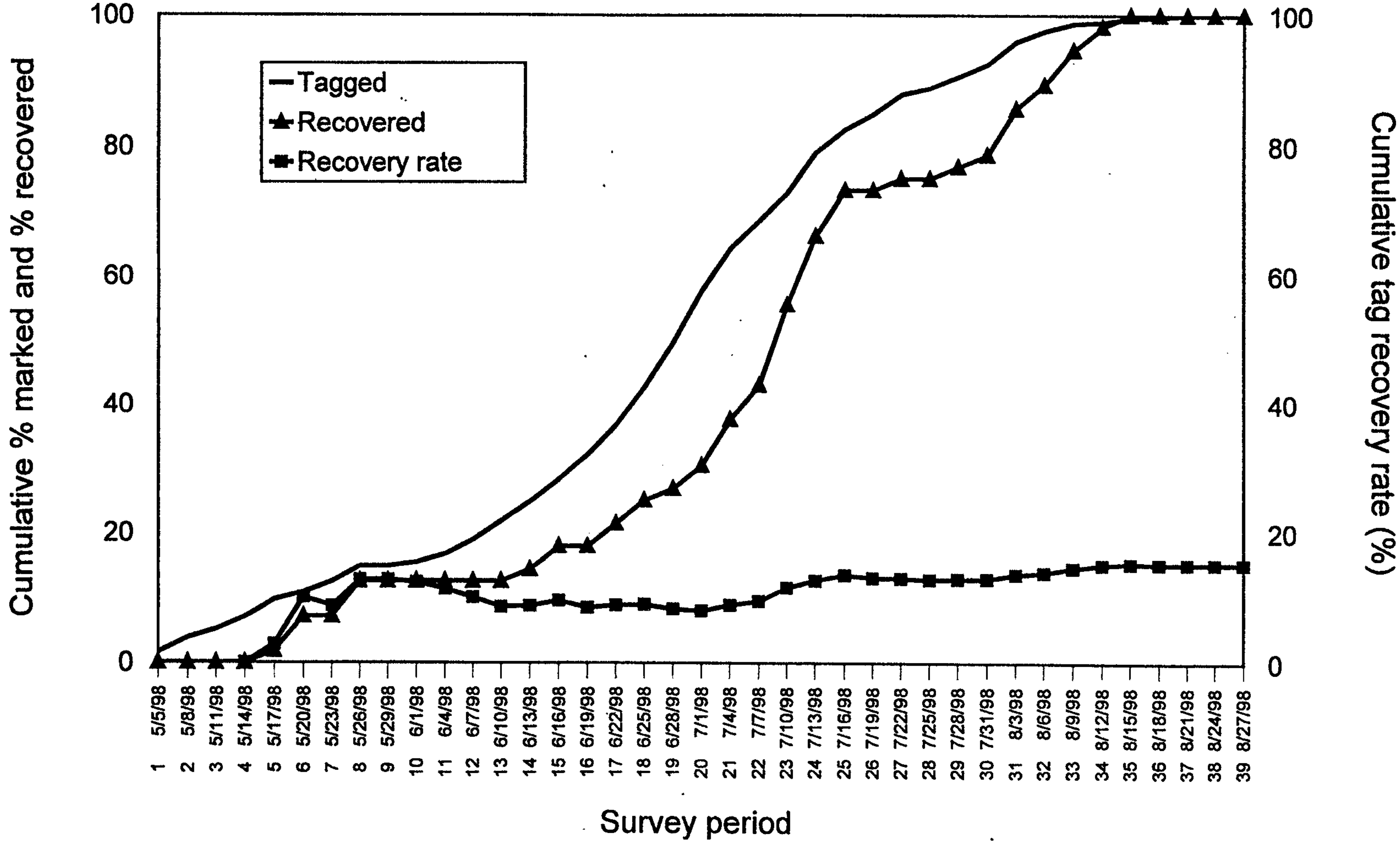

Figure 6. Comparison of temporal distribution of tagging versus recovering of tagged fresh carcasses and tag recovery rate (n tagged/n recovered) during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.